November 2000

Vol. 24 No. 11

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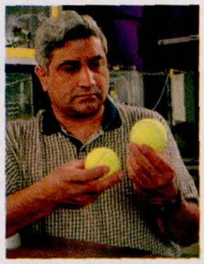

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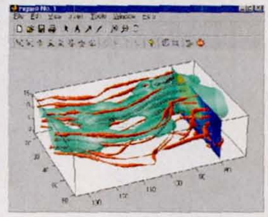

ON THE COVER

Developed for Walter Meano Engineering, this pump motor can be driven by pneumatic, hydraulic, electric, or gasoline motors. All elements of the pump were created in Solid Edge mechanical CAD software from Unigraphics Solutions, St. Louis, MO. The latest release of the software, Solid Edge Version 9, is one of the featured products in our Special Coverage on Design & Analysis Software, which begins on page 30.

(Image courtesy of Unigraphics Solutions. Image design by John Malan of John Malan Design, Johannesburg, South Africa)

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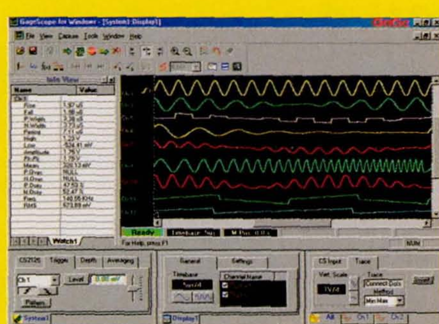

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NASA's Technology Sources

If you need further information about new technologies presented in *NASA Tech Briefs*, request the Technical Support Package (TSP) indicated at the end of the brief. If a TSP is not available, the Commercial Technology Office at the NASA field center that sponsored the research can provide you with additional information and, if applicable, refer you to the innovator(s). These centers are the source of all NASA-developed technology.

Ames Research Center
Selected technological strengths: Fluid Dynamics; Life Sciences; Earth and Atmospheric Sciences; Information, Communications, and Intelligent Systems; Human Factors.
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Dryden Flight Research Center
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jenny.baer-riedhart@dfrc.nasa.gov

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merle.mckenzie@jpl.nasa.gov

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cto@grc.nasa.gov

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NASA ON-LINE: Go to NASA's Commercial Technology Network (CTN) on the World Wide Web at **http://nctn.hq.nasa.gov** to search NASA technology resources, find commercialization opportunities, and learn about NASA's national network of programs, organizations, and services dedicated to technology transfer and commercialization.

NASA Program Offices

At NASA Headquarters there are seven major program offices that develop and oversee technology projects of potential interest to industry. The street address for these strategic business units is: NASA Headquarters, 300 E St. SW, Washington, DC 20546.

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NASA's Business Facilitators

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Lewis Incubator for Technology
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Mississippi Enterprise for Technology
Stennis Space Center, MS
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Julie Holland
NASA Commercialization Center
Pomona, CA
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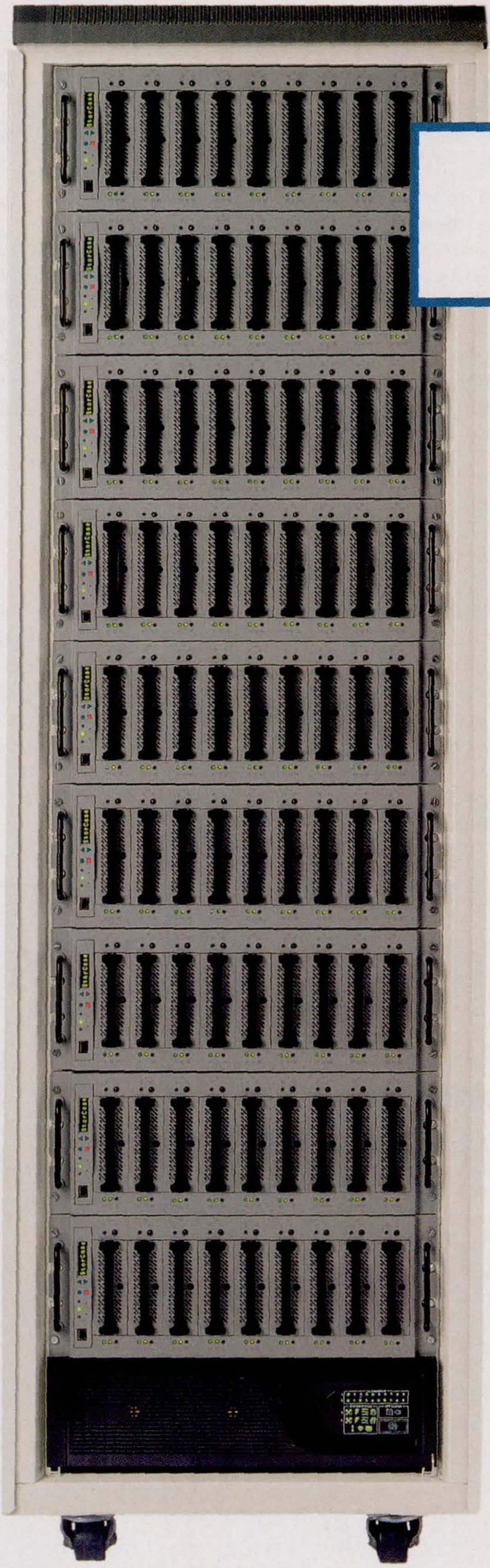
If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622.



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I am looking for any information available on inflatable antennas. Can you provide any background on any NASA projects in this area?

Mohammed Haseeb
mhaseeb@rediffmail.com

*(**Editor's Note:** Mohammed, the first place you can look for information on NASA developments in inflatable antennas is the* NASA Tech Briefs *web site at www.nasatech.com. Click on the Technical Support Packages heading, and go to the Electronic Components & Systems category. There, you'll find additional information you can download regarding NASA's Jet Propulsion Laboratory's research on "Inflatable Reflectarray Antennas," which we covered in our October 1999 issue.)*

I need to measure the speed of light over a total distance of about 18" to 30" (fixed). I am looking to detect changes or "deltas" in that speed or time of travel corresponding to a distance of about 0.1" or 2.5 mm, but anything that approaches this (even 1") is not possible today, to my knowledge. The signal is the initial edge of two similar light flashes, so optical fiber or optical/electronic methods may apply. I believe some form of heterodyne system or phase measuring approach may hold the key.

John K. Grady, P.E.
978-772-3303

Our company, along with the Renewable Energy Development Institute, has developed methods for converting Fire Risk Materials (FRM) into saleable products. One product converts wood into hydrogen and carbon monoxide; another removes particulate and aerosols from the gases, and reduces NO_x. We need to cool the gases between the products from 700°C to about 150°C. The NASA Patents page in your August issue featured the "Thermally Regenerative Battery with Intercalatable Electrodes and Selective Heating Means" from the Jet Propulsion Laboratory. This invention appears to be able to generate and store electric power when exposed to such temperatures. We would like to know if there are others available as well. Thank you.

R. Edward Burton
EBC Company
707-459-6219

*(**Editor's Note:** Edward, visit the NASA Jet Propulsion Laboratory web site at www.jpl.nasa.gov for additional information on research in thermal battery technology. NASA's Glenn Research Center in Cleveland also conducts research on thermal batteries. You can visit their site at www.grc.nasa.gov.)*

NASA Patents

Over the past three decades, NASA has granted more than 1000 patent licenses in virtually every area of technology. The agency has a portfolio of 3000 patents and pending applications available now for license by businesses and individuals, including these recently patented inventions:

Process and Equipment for Nitrogen Oxide Waste Conversion to Fertilizer

(U.S. Patent No. 6,039,783)

Dale E. Lueck and Clyde F. Parrish, Kennedy Space Center

The patent describes a new emissions control system for fluid streams containing nitrogen and oxygen, particularly compounds selected from nitrogen oxide generating processes, systems, and compositions, including oxidizer scrubbers that are used to eliminate current oxidizer liquor waste from hypergol-energized propellant systems. Since fueling and deservicing spacecraft constitute the primary operations in which environmental emissions of nitrogen oxides occur in the U.S. space program, the process and apparatus described will eliminate the second largest waste stream at the Kennedy Space Center (KSC). This invention provides the equipment and procedures used to monitor and control the conversion of the scrubber liquor to fertilizer, while reducing the scrubber emissions.

Micromachined Thermoelectric Sensors and Arrays and Process for Producing

(U.S. Patent No. 6,046,398)

Marc C. Foote, Eric W. Jones, and Thierry Caillat, Jet Propulsion Laboratory

The inventors report that they have produced arrays with up to 63 micromachined thermopile infrared detectors on silicon substrates. Each detector consists of a suspended silicon nitride membrane with 11 thermocouples of sputtered BiTe and BiSbTe thermoelectric film. In response time, specific detectivity (D*), and responsivity, these represent the best performance reported to date for an array of thermopile detectors. These detectors are ideal for some applications due to their simple system requirements. They operate over a broad temperature range and are insensitive to drifts in substrate temperature. They are passive devices, generating a voltage output without electrical bias or chopping. For some applications thermopile detectors can be supported by simpler, more reliable systems consuming less power than bolometers, pyroelectric or ferroelectric detectors. The array includes means for enhancing thermal isolation of the hot junction of each detector from those of the other detectors, and a micromachined substrate for supporting the thin dielectric membrane such that the substrate is opposite the cold junction and there is an opening or window opposite the hot junction.

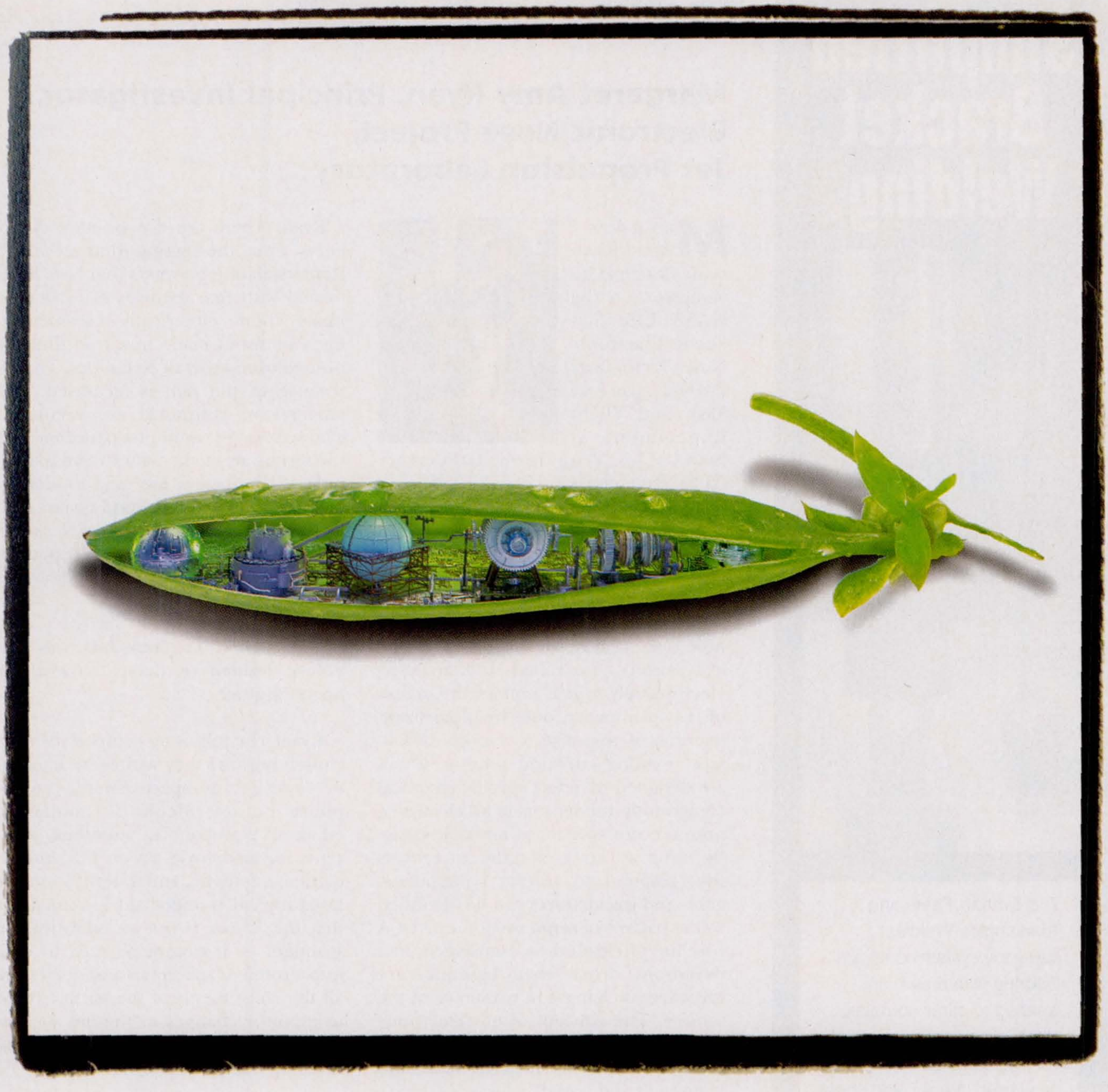
Manipulation of Liquids Using Phased Array Generation of Acoustic Radiation Pressure

(U.S. Patent No. 6,029,518)

Richard C. Oeftering, Glenn Research Center

The purpose of this invention is to control or manipulate liquids by using an acoustic phased array that produces high-energy acoustic waves, thereby creating a force called acoustic radiation pressure and a nonlinear effect called acoustic streaming. A plurality of acoustic transducer elements is arranged in a linear one-dimensional array, a two-dimensional array, or in an annular array of concentric transducer rings. The individual transducer elements are electrically driven as individual channels. Each channel is under a common controller. The timing of the acoustic wave emission is controlled by delaying or advancing the emission's time event based on a set of reference points. By adjusting the time shift or phase shift, the elements emit a wave pattern such that constructive or destructive interference waves cause a single wave pattern to emerge. Thus a shifted array can synthesize a wave or wave pattern that can be steered at angles relative to the axis of the array or can be caused to diverge or converge to a predetermined focal point. The convergence of acoustic waves on a singular focal point creates high intensity.

For more information on the inventions described here, contact the appropriate NASA Field Center's Commercial Technology Office. *See page 14 for a list of office contacts.*



Margaret Amy Ryan, Principal Investigator, Electronic Nose Project, Jet Propulsion Laboratory

Margaret Amy Ryan is the Principal Investigator on the NASA Life Sciences Electronic Nose Technology Development Task and Flight Experiment at NASA's Jet Propulsion Laboratory (JPL), Pasadena, CA.

***NASA Tech Briefs:* What is an "electronic nose" and how long has this type of device been in existence?**

Margaret Amy Ryan: An electronic nose is an array of weakly specific chemical sensors, controlled and analyzed electronically, which mimics the action of the mammalian nose by recognizing patterns of response to vapors. Unlike most existing chemical sensors, which are designed to detect specific chemical compounds, the sensors in an electronic nose are not specific to any one vapor. By using an array of different sensors that respond to several compounds, gases and gas mixtures can be identified by the pattern of response of the array. A baseline of clean air is established, and deviations from that baseline are recorded as changes in resistance of the sensors. The concept of an "electronic nose" has been discussed since the mid-1980s, and several such devices have been built and tested.

NTB: Why is this technology important to NASA?

Ryan: The ability to monitor the constituents of recycled breathing air in a closed chamber is important for use in environments such as the Space Shuttle, the Space Station, and planned human habitats on Mars or the Moon. The best real-time, broadband air-quality monitor now available in space habitats is the human nose, which is limited by factors such as fatigue, exposure to toxins, and inability to detect some compounds.

NTB: How does JPL's ENose differ from earlier versions of the device?

Ryan: There are two primary differences. First, the sensing films are made from insulating polymers that have been loaded with fine particles of carbon to make them electrically conducting. Each sensor is made of a thin film deposited over a pair of electrodes. The resistance of the film is measured, and changes in resistance are recorded. Those changes result in a pattern across the sensor array; the pattern and magnitude of the pattern are used to identify and quantify the compound responsible for the change. Second, the ENose was designed to quantify certain compounds at the Spacecraft Maximum Allowable Concentration (SMAC) level.

NTB: What contaminants was the ENose trained to detect aboard the Space Shuttle?

Ryan: The following compounds were chosen because they had been detected or reported in Space Shuttle atmosphere before: alcohols (methanol, ethanol, 2-propanol), ammonia, benzene, formaldehyde, Freon 113, indole, methane, toluene, and water (% relative humidity). It is important to remember that the ENose is not an analytical instrument — it cannot be used to walk into a room or spacecraft and determine all the constituents of the air. It is used to monitor changes in the air, such as from spills, leaks, air filters that need to be changed, or incipient fires.

NTB: What are some potential commercial applications for the ENose?

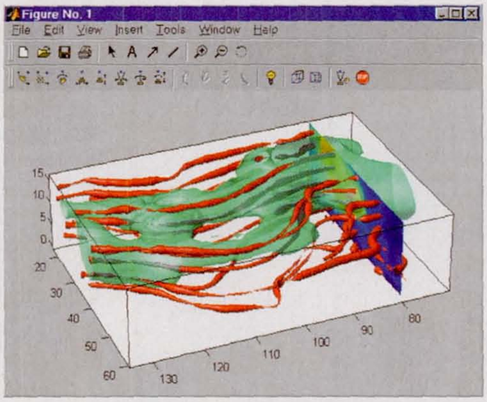
Ryan: Electronic noses already have been used in the food industry to monitor the production of coffee, beer, wine, and bread. An electronic nose can be used to monitor the air in any enclosed space, such as a submarine, an aircraft, or closed working spaces such as tunnels. The electronic nose also could be used in medical diagnoses: It could detect compounds distinctive of particular diseases and differentiate bacteria. Another potential application is the detection of a fire before the blaze erupts.

A full transcript of this interview appears online at www.nasatech.com. Dr. Ryan can be reached at mryan@jpl.nasa.gov.

UpFront

PRODUCT OF THE MONTH

The MathWorks, Natick, MA, has released version 6 of MATLAB technical computing software as part of Release 12 of its product family. MATLAB 6 includes a new desktop front-end and integrated tools that provide access to the software's math, analysis, visualization, and programming capabilities. New tools simplify common tasks such as importing data, performing analyses, and creating informative graphics. Also featured are optimizations to the product's core matrix computing and signal processing engines, and access to hardware devices and Java directly from MATLAB. Desktop components include a cross-product, searchable, HTML-based help reader, and a Workspace Browser for loading, viewing, and editing data. New Data Statistics and Basic Fitting tools allow users to superimpose statistical calculations and curve fits — both text and graphics — directly on MATLAB plots. New functions enable viewing of 2D images, surfaces, and volumes as transparent objects; and visual tools for controlling point of view.



For More Information Circle No. 756

Tennis, Anyone?

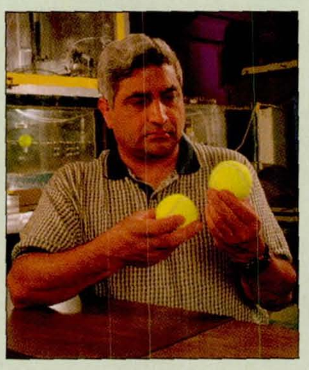
NASA aerodynamics technology may help create more competitive tennis matches, much like new racket technologies have led to more powerful serves. To slow the game down, the International Tennis Federation (ITF) recently approved testing of a new ball that is 6.5 percent larger in diameter than the current ball. They used data collected by Dr. Rabi Mehta and the wind tunnels at NASA's Ames Research Center in Moffett Field, CA.

The concern is that the top players can serve at about 150 miles per hour, reducing the number of rallies. Mehta explained that "a larger ball will slow things down; the trick is to figure out how much." That was the objective of experimental testing conducted at ITF facilities in England, and at Ames.

Mehta's team measured the drag on regular and larger balls over a range of flow speeds in Ames' 15 x 15″ wind tunnel. "Initially, we could not determine why the drag on tennis balls is so much higher than that on other sports balls," Mehta said. "Then we realized that the fuzz on the ball plays a much larger role in the aerodynamics than had been anticipated in the past."

According to Mehta's tests, "if you have a smooth ball, such as a ping-pong ball, it produces a large air wake, like that of a motor boat. The ball's large wake creates drag that slows the ball's flight. If you add roughness, like the dimples on a golf ball, air disturbance near the ball's surface actually helps produce a smaller air wake that creates less air drag, and the ball can go farther." Mehta explained that a smooth golf ball might only go 100 yards, compared to the 300 yards covered by today's dimpled balls.

For more information, visit Ames Research Center's Office of Communications at http://amesnews.arc.nasa.gov.



Dr. Rabi Mehta compares a regulation-size tennis ball with the proposed larger ball.

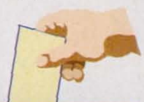
Young at Heart

The movie "Space Cowboys" traces the fictitious voyage of retired astronauts called upon to return to duty for a Space Shuttle mission. Well, in the real world, retired NASA space veterans from the Jet Propulsion Laboratory (Pasadena, CA) are helping doctors and patients with medical expertise forged in their years of NASA service. The Volunteer Professionals for Medical Advancement, a group founded by Herman Bank, is comprised of 65- to 85-year-old retired NASA colleagues who brainstorm, research, and develop new medical technologies.

Among the medical advancements for which the group has been responsible are:

- Design of an automated oxygen-enrichment system for premature babies, developed with Los Angeles County and USC Medical Center, that removes the inaccuracies of manually controlled oxygen systems.
- Creating, with the Children's Hospital of Los Angeles, an advanced-database, private computer network for pediatricians that will provide a depository for historical data of diagnoses, research, treatments, and results, helping doctors correspond about children's illnesses.
- Solving a blood-clot problem found with a stent that could cause heart attacks. The group introduced an electropolishing process, developed for the space program, that provides a super-smooth stent surface.

For more information, contact Gabrielle Birchak-Birkman of JPL at 818-393-4359.



Cast Your Vote!

We need our readers to make one more voting decision in this election year — choosing the Readers Choice Product of the Year. Look for the ballot in next month's issue and cast your vote for the most innovative product of 2000. You could win some valuable prizes, too!

NASA Announces Top Software Awards for 2000

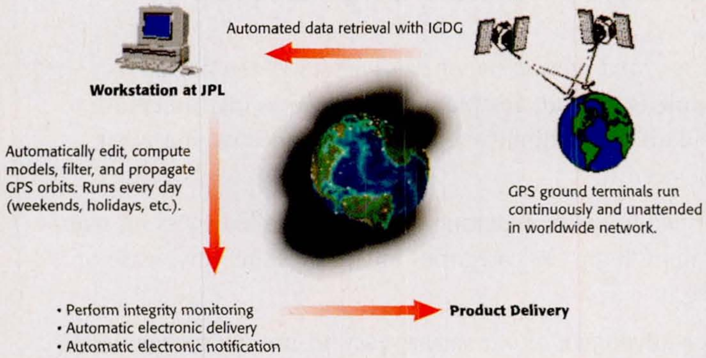
Each year, NASA's Inventions and Contributions Board and the NASA Chief Information Officer select the NASA Software of the Year. The award, which is the largest of its kind in the US, honors the top software programs submitted from a field of government agencies, corporations, and universities.

The 2000 winner is Internet-Based Global Differential GPS (IGDG), developed at NASA's Jet Propulsion Laboratory in Pasadena, CA. IGDG is a C-language package that provides an end-to-end system capability for GPS-based real-time positioning and orbit determination. For more information on IGDG, the other winners, and the awards sponsors, visit: www.hq.nasa.gov/office/codei/swy2000win.html.

Positioned for Success

According to Stephen M. Lichten, one of the inventors of IGDG, the software began as a small task associated with the development of a "micro GPS" instrument in the Telecommunications and Mission Operations Directorate at JPL. The group developed a small piece of software to do real-time onboard spacecraft positioning, and further enhanced the software to provide ground and near-Earth user positioning as well as orbit determination.

With IGDG, the JPL team has proven that ultra-precise (10 cm) real-time positioning is possible globally with GPS. Local or regional systems are available commercially, but none provide global or space coverage, and none can come close to IGDG's positioning accuracy of within a meter.



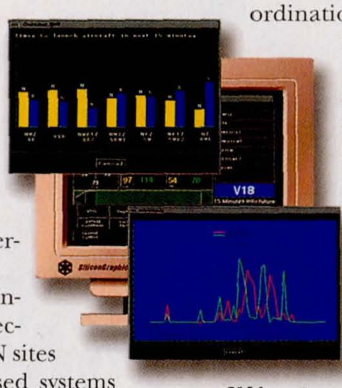
IGDG is being used to operate and control real-time GPS data streaming from NASA's Global GPS Network (GGN), which consists of about 60 sites — a subset of which is equipped with computers and Internet connections. IGDG returns GPS data in real time from remote receivers, then collects, edits, and compresses the raw GPS data at the remote site. It then transmits the packetized data over the Internet to the processing center at JPL. The data is encoded, and provided over the Internet to authorized users.

IGDG's use of the public Internet helps make data collection from the upgraded GGN sites affordable, as telephone-based systems continue to prove expensive for this type of application. The software also was used for precise orbit determination of the Space Shuttle, and to assess the performance of onboard GPS receivers.

The Federal Aviation Administration (FAA) and several contractors saw the significance of IGDG, and adopted it into its Wide Area Augmentation System (WAAS) program as the core software for determination of GPS corrections. WAAS improves the accuracy, integrity, and availability of basic GPS signals. The system allows GPS to be used as a primary means of navigation for en-route travel and non-precision approaches in the U.S. WAAS will provide pilots in U.S. airspace with meter-level accurate knowledge of their positions in real time through use of these GPS corrections. IGDG, and its use as the WAAS core software, will enable safer aviation, and is expected to save more than $10 billion in the first decade of its operation in reduced fuel costs and airport expenses.

Smooth Flying

The second-place winner in the 2000 NASA Software of the Year Awards is the Surface Movement Advisor (SMA) from NASA's Ames Research Center in Moffett Field, CA. SMA is a joint NASA and FAA project designed to improve the coordination of airport surface traffic flow.



SMA system

SMA is based on a client-server architecture. A fiber backbone among the airlines, airport management, ramp towers, and the FAA control tower links the SMA system together. Various traffic data is collected in real time by the SMA server. The system integrates airline schedules, gate information, flight plans, radar feeds, and runway configurations. This integrated information is then re-transmitted over the network system and shared among the key players at the airport.

Future SMA projects include a low-visibility tower support system that will provide vision aids for air traffic controllers to better see the airport in low-visibility conditions such as fog, smog, smoke, or snow.

More NASA Winners

The following software programs were named runners-up in this year's contest:

- Orbiter Interface Unit/Early Communication System Flight Software from Johnson Space Center in Houston, TX.
- Chandra Flight Software from Marshall Space Flight Center in Huntsville, AL.
- GPS Enhanced Orbit Determination (GEODE) Software from Goddard Space Flight Center, Greenbelt, MD.

NASA awarded Honorable Mentions to these projects:

- Embedded Operation of Fourier Transform Infrared Spectrometer from Kennedy Space Center, Florida.
- Coupled Structural, Thermal, Electronmagnetic, Acoustic Analysis/Tailoring of Graded Composite Structures (CSTEM) from John H. Glenn Research Center, Cleveland, OH.
- Aviation Safety Analysis and Functionality Evaluation (ASAFE) from Langley Research Center, Hampton, VA.

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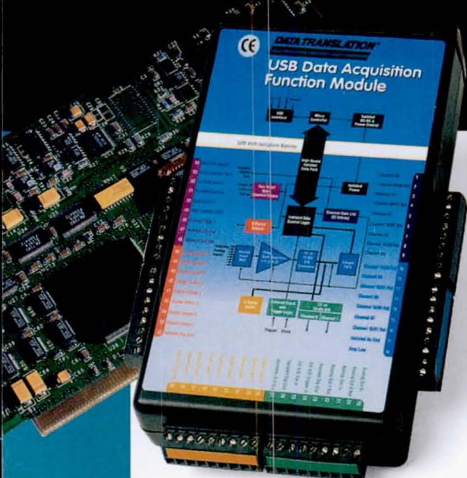

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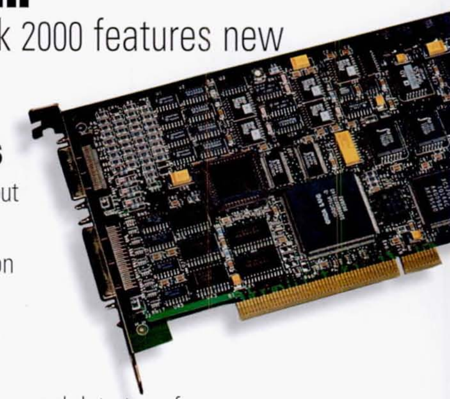

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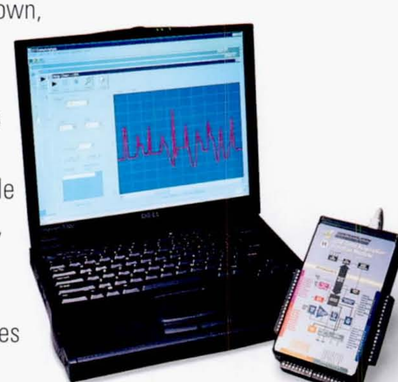

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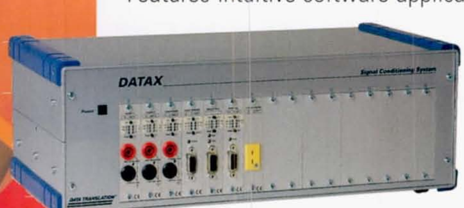

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November 2000

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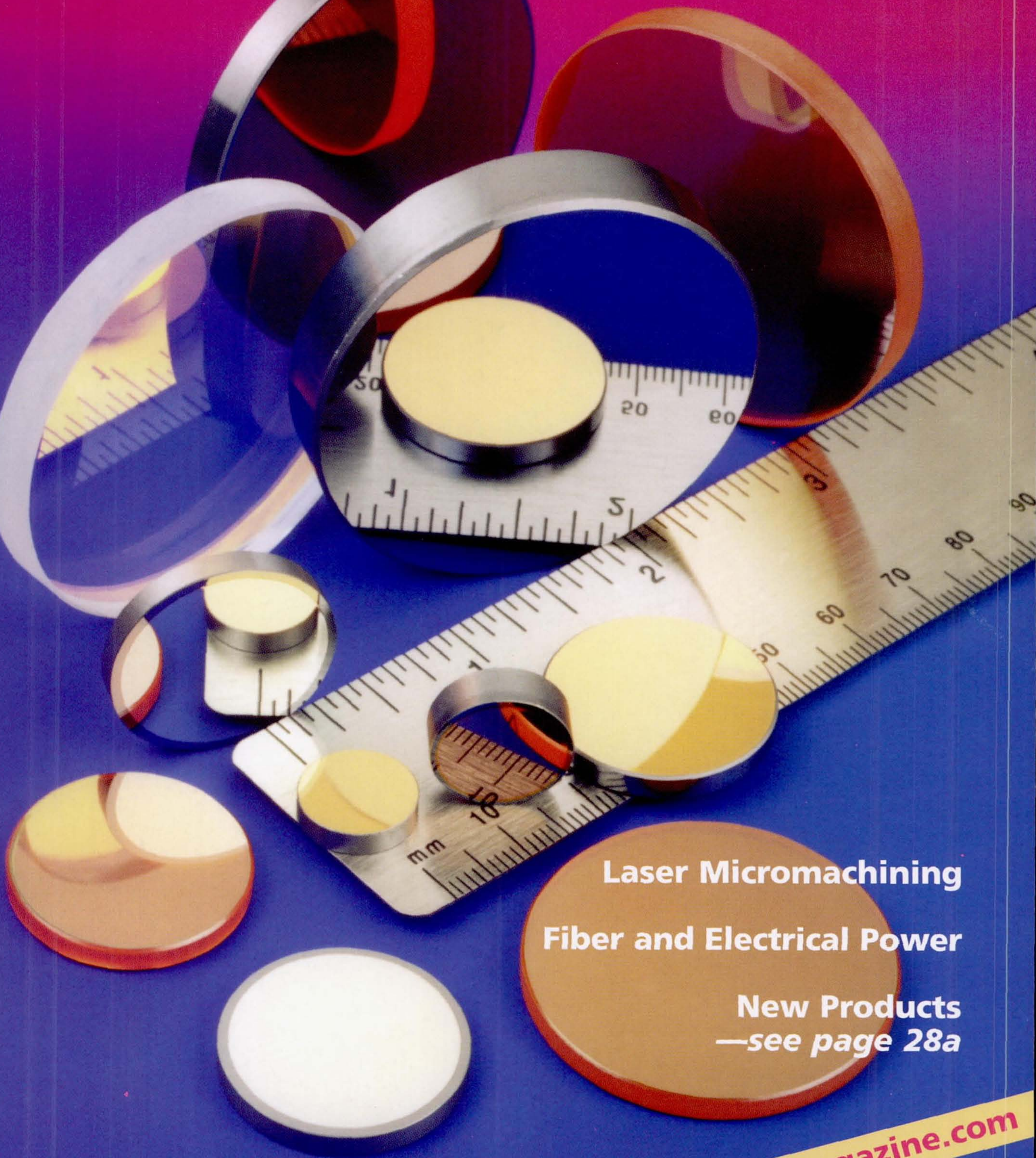

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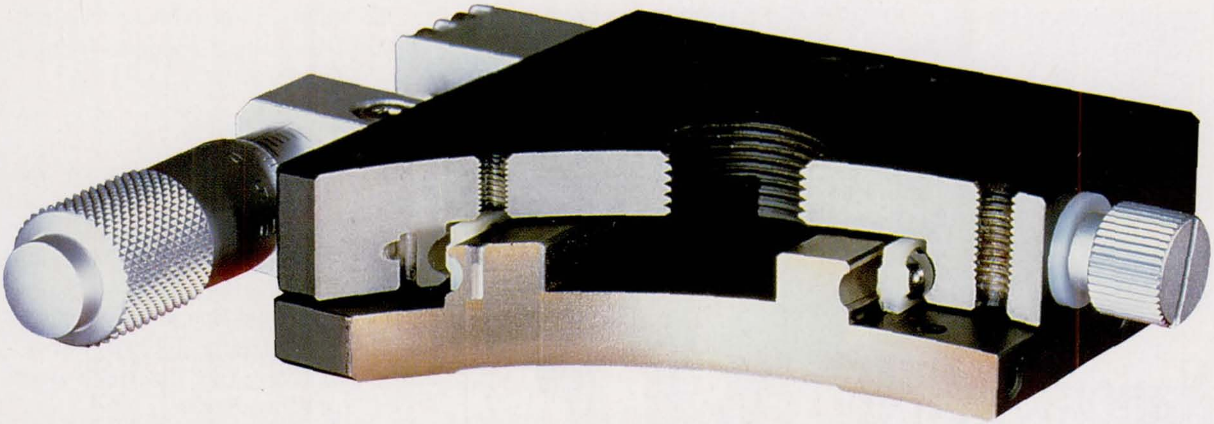

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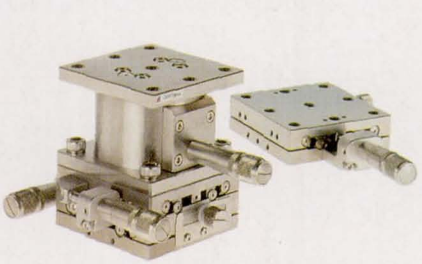

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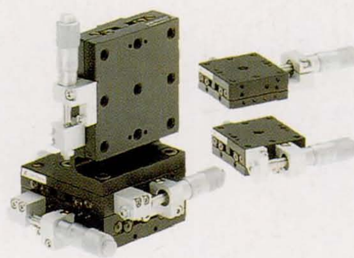

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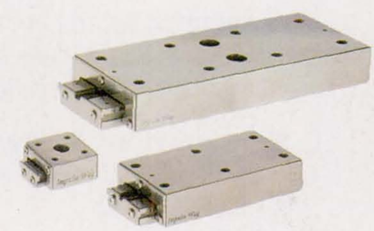

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Supplement to *NASA Tech Briefs'* November 2000 Issue Published by Associated Business Publications Int.

Features

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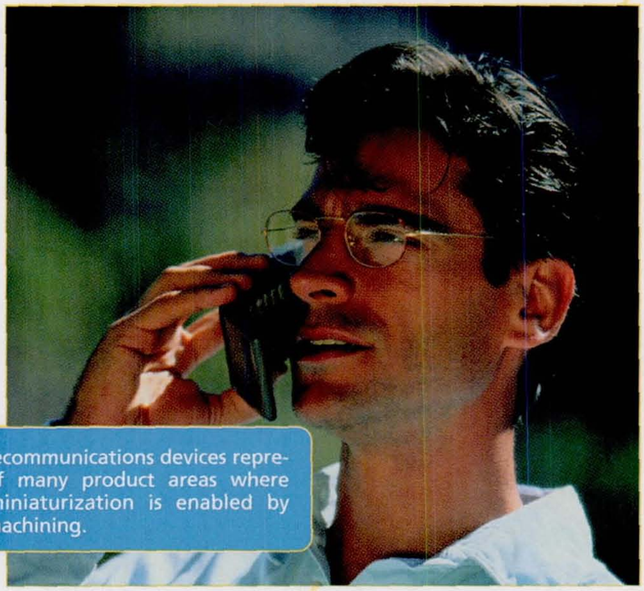
On the cover: *Shown is Laser Research Optics' line of carbon dioxide laser turning mirrors.*

Photo courtesy Laser Research Optics.

LASERS THRIVE IN MICROMACHINING

All-solid-state lasers spur rapid applications growth, particularly in the UV.

Products as diverse as biomedical devices and cellular phones are characterized by a common trend of increasing miniaturization. This has created a demand for new micromachining methods, to produce holes, grooves, cuts or other physical features with dimensions as small as a few microns. A laser beam is an ideal tool for most of these micromachining tasks; the beam can be focused to produce different shapes and spot sizes for process flexibility, there is no tool wear so product consistency is always high, and laser processing is very compatible with cleanroom operation and automated robotic processing. All-solid-state lasers maximize these advantages, and result in lower overall process costs. This article briefly reviews present and developing all-solid-state laser technology and discusses some representative applications for infrared, visible and ultraviolet lasers.



Personal telecommunications devices represent one of many product areas where increased miniaturization is enabled by laser micromachining.

All-solid-state lasers consist of one or more arrays of semiconductor lasers, whose output is coupled into a solid-state laser crystal mounted in a compact laser cavity. Fiber coupling of the semiconductor laser arrays allows them to be located external to the sealed laser cavity, which in turn allows simple field replacement (after 10,000 hours or more), with no optical realignment. (At Spectra-Physics, we refer to this unique design feature as FC*bar*™ technology.)

The laser crystal is usually neodymium yttrium aluminum garnet (Nd:YAG) or neodymium vanadate (Nd:YVO_4), with vanadate preferred for high power and high repetition rates. The majority of models operate in a Q-switched (pulsed) mode, with pulse energies up to 2 millijoules and repetition rates up to 200 kHz. These all-solid-state lasers feature simple turnkey operation, excellent output beam characteristics, long maintenance-free lifetimes with high reliability, consistent pulse energies, a small footprint, and no requirement for external cooling water.

In terms of output wavelength, all-solid-state lasers generate near-infrared output (at 1.05 or 1.06 microns), which can be frequency-doubled or tripled to produce green or ultraviolet light using nonlinear optical crystals. In the past year, the utility of these lasers was significantly increased with the advent of pre-aligned doubling and tripling modules, which allow users to rapidly switch between the different wavelengths, with no need to realign the laser. All three wavelength domains are used in micromachining, so this modularity can be particularly useful for optimizing micromachining conditions for new materials.

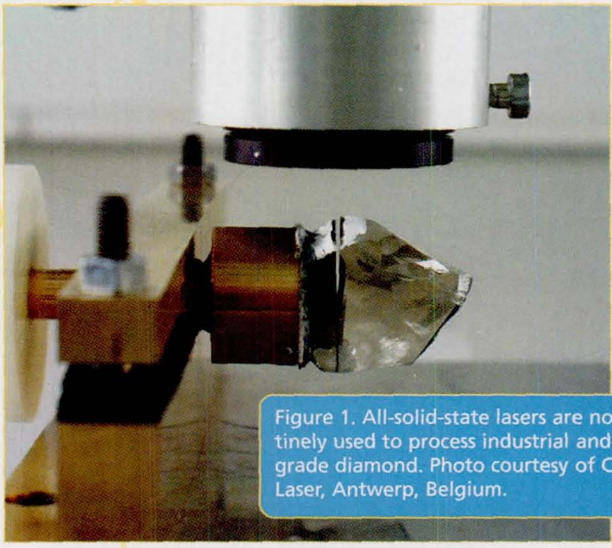
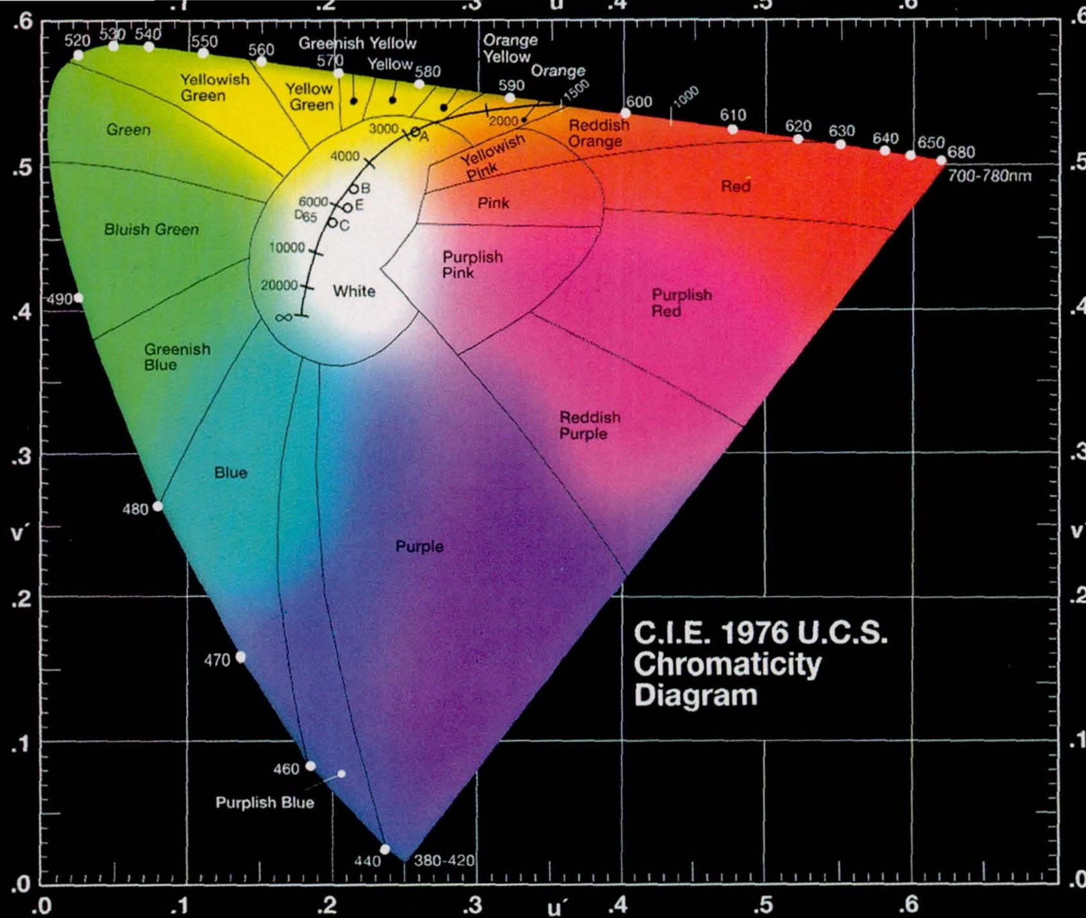


Figure 1. All-solid-state lasers are now routinely used to process industrial and gem-grade diamond. Photo courtesy of CNC Laser, Antwerp, Belgium.

Infrared Applications

Near-infrared laser operation offers the lowest cost of ownership because no frequency doubling or tripling module is required. One important infrared application is computer hard-disk texturing. Here, a ring-shaped landing zone is created around the disk center to prevent the parked read/write head from sticking to the polished disk surface. This zone typically consists of 500,000 separate surface bumps, each measuring around 5 microns in diameter, but only 20 nm in height. Each circular, "sombrero"-shaped bump is produced by an individual laser pulse from a Q-switched Nd:YVO_4 laser at 1064 nm.

An all-solid-state laser offers several unique advantages in this application. High pulse-energy stability and a low, consistent M^2 value ensure that every bump will have the same shape and height ($\pm$ 1 nm). Beam pointing is just as critical, because the beam delivery system may include more than 20 optical elements in order to produce a diffraction-limited spot at the disk surface; beam shift would lead to wavefront distortion and im-



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properly formed bumps. Also, the small footprint of these air-cooled lasers is an advantage in this cleanroom application.

Another near-infrared application is processing of industrial and gem-grade diamonds (e.g., cutting, drilling, engraving, bruting). In principle, true diamond does not absorb at the 1.06-micron wavelength. However, even a high-grade diamond contains enough graphite characteristics to ensure absorption of the 1.06-micron laser beam. Traditionally this application relied on lamp-pumped solid-state lasers. But the ability to focus an all-solid-state laser to a smaller spot, together with superior pulse-to-pulse stability, enables it to process a diamond at similar speeds to those of a higher-power lamp-pumped laser — but with noticeably less material loss and heat-related stress damage (see Figure 1).

Near-infrared lasers are also used for trimming of thick-film resistors and capacitors. Here the laser is used to make small cuts in one or more electronic components in order to fine-tune the electrical values.

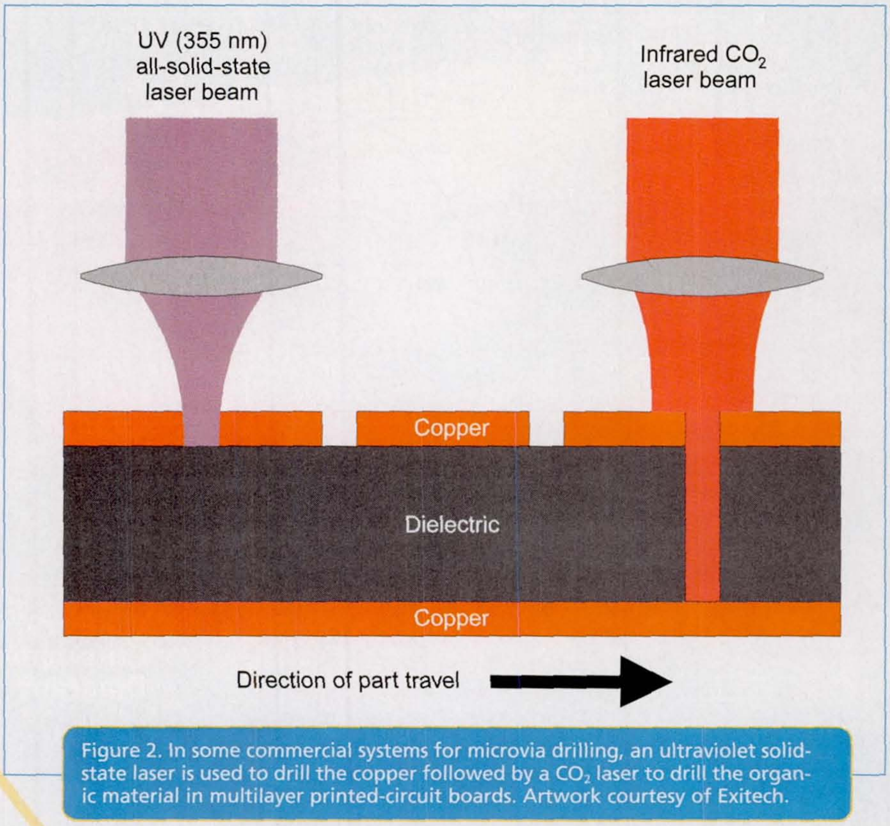

Figure 2. In some commercial systems for microvia drilling, an ultraviolet solid-state laser is used to drill the copper followed by a CO_2 laser to drill the organic material in multilayer printed-circuit boards. Artwork courtesy of Exitech.

Visible Applications

Some materials are processed more effectively with visible laser light because of their spectral absorption characteristics. This includes some plastics, thin-film dielectrics, and certain metals, most notably copper. In fact, high-power green (532-nm) lasers are now starting to appear in systems for machining copper on printed-circuit boards (PCBs).

A major copper micromachining application involves voltage-controlled oscillators or VCOs. This is an oscillator circuit that contains a varactor diode. The frequency of the oscillator is determined by the magnitude of an applied voltage across this diode. The explosive growth of telecom and datacom technology, particularly cell phones, has created a huge demand for VCOs. After VCO fabrication, the device is powered up and copper is trimmed in order to fine-tune the actual relationship between voltage and frequency in a closed-loop adjustment process.

Ultraviolet Applications

Ultraviolet micromachining offers several advantages that have made it the fastest-growing segment of this market. Ultraviolet laser light ablates material by directly breaking molecular bonds, whereas longer-wavelength lasers remove material by heating, boiling, and vaporizing. This cold atomization process produces virtually no heat-affected zone (HAZ) and no recast material. This allows very fine details and microscopic structures to be machined even in delicate and/or thin materials. Moreover, diffraction decreases with wavelength, so that ultraviolet light can be focused to smaller spot sizes than visible or infrared. In addition, most materials have a higher absorption coefficient in the ultraviolet than at other wavelengths, so that lower pulse energies are often acceptable.

All-solid-state UV lasers (355 nm) are now widely used in the electronic packaging industry to produce microvias. These tiny through and blind holes allow selective electrical connections between multiple planes within a multilayer board or packaging substrate. This technology underpins most of the recent electronics miniaturization methods, such as ball grid arrays (BGAs), for example. For microvia production, some commercial systems incorporate both a CO_2 laser and a UV laser. The latter is used to drill through the copper laminate, followed by the CO_2 laser to rapidly drill the organic layers (see Figure 2).

MEMS (microelectromechanical system) construction is another high-growth application for UV laser micromachining. As their name suggests, MEMS devices contain small mechanical parts whose position, function, and/or operation is selectively switched on and off by electrical activation. Dense fiber optic networks are now emerging as an important market for MEMS devices. For example, multichannel switches and routers which contain an array of individually movable micromirrors on a single chip are now clearing Bellcore certification processes and undergoing field tests. Although an excimer laser and

mask have been used in some of these applications, the all-solid-state laser is preferred because its focusable beam permits fine adjustment during the actual MEMS fabrication process. With a mask process, any improperly produced MEMS elements have to be corrected and adjusted in a separate process following extensive QC testing.

UV lasers are also being used to drill holes and grooves in medical devices such as microcatheters, as well as to produce microchannel plates and arrays to facilitate pharmaceutical development and genetic research.

Future Trends

Two newly emerging laser technologies promise to have an impact on laser micromachining and therefore merit some discussion. The first is quasi-CW lasers based on saturable Bragg reflector (SBR) devices. (The SBR was originally developed and patented by Lucent Technologies.) It is a multilayer cavity mirror which naturally forces a laser to operate in a mode-locked manner; the output consists of a stream of ultrafast (femtosecond or picosecond) pulses at a repetition rate as high as hundreds of MHz. The first commercial products based on this technology, including the Spectra-Physics Vanguard™, were launched earlier this year.

The advent of rugged, mode-locked lasers will enable cold processing in all three wavelength regimes: infrared, visible, and ultraviolet. Simply stated, the pulse duration is so short that thermal dissipation is very effective and peripheral damage is almost nonexistent, even in the near-infrared. In addition, the high peak power of these lasers enables very efficient harmonic generation of quasi-CW ultraviolet light, finally providing an alternative to high-power gas lasers in CW applications.

The other important recent development is the use of a resonant build-up cavity for efficient harmonic generation with true CW lasers. This has led to the first commercial CW lasers with 266-nm fourth-harmonic output. These lasers provide an all-solid-state alternative for deep UV applications currently relying on power-hungry water-cooled ion lasers, including semiconductor wafer testing and writing fiber Bragg gratings (FBGs).

For more information, contact the author of this article, Mark Keirstead, marketing manager, OEM Business Unit, Spectra-Physics Lasers Inc., Mountain View, CA; e-mail: mkeirstead@splasers.com; www.splasers.com.

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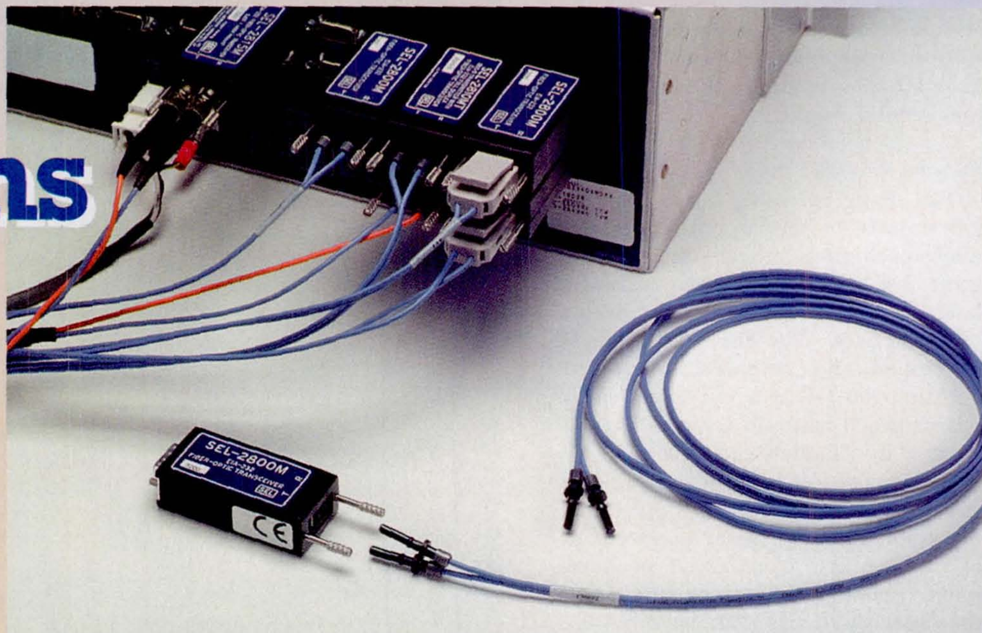

Fiber optic transceivers and FiberWire connected to a communications processor.

Monitoring and control systems in the electric power industry face numerous communications obstacles. Electrical substation and generating plant environments include electromagnetic interference, electrostatic discharge, extremes of temperature, vibration, high-current faults, and high voltages. To provide reliable, safe, twenty-four-hour-a-day electricity to our homes and workplaces, power companies depend on protection, monitoring, and control systems for generation, transmission, and distribution. To help provide clear communication and help protect their employees from dangerous high voltage, many power companies choose fiber optic cable to connect devices in their monitoring and control systems.

Schweitzer Engineering Laboratories (SEL) in Pullman, WA, works to make electric power safer, more reliable, and more economical. The company designs and manufactures microprocessor-based devices to protect, monitor, and control power system lines and apparatus. These devices, including protective relays and communications processors, must perform numerous functions autonomously, and communicate with each other and with the instrumentation and control (I&C) system.

The Benefits of Fiber

To help overcome communications obstacles in power stations, SEL products use Lucent Technologies' FiberWire™ optical products to communicate with protection, monitoring, and control devices. FiberWire's intrinsic EMI/ RFI immunity makes it ideal for harsh electrical environments. FiberWire also enables easy field connector termination, easy testing with visible light, damage-resistant cable, and electrical isolation. SEL manufactures a line of fiber optic transceivers to bring the advantages of FiberWire to devices with EIA-232 serial ports, and provides selected instrumentation and control devices with built-in fiber optic interfaces. The SEL transceivers also allow longer cable distances than the 15-meter (50-foot) limitation of EIA-232 with metallic cables. SEL transceiver models support multimode FiberWire links of up to 500 meters (1640 feet) and 15 kilometers (9.3 miles). A single-mode fiber model provides links up to 80 kilometers (50 miles).

In the event of a ground fault, very high currents, through the resistance of the ground, cause a difference in electrical potential from one location to another. This change in potential can damage equipment and injure people. FiberWire provides the necessary electrical isolation to drastically reduce the risks to people and equipment.

The Role of Relays

Microprocessor-based protective relays sense electrical conditions and rapidly trip a breaker to protect people, property, and the power system. Because they include internal diagnostics, they can remain in service without interruptions for periodic testing. Beyond their primary protective functions, they include automatic control to restore service, metering and demand metering reports, sequential event reports, and event reports with fault type and location and oscillographic data snapshots. The same I/O connections that the relay uses for protection also offer control and indication

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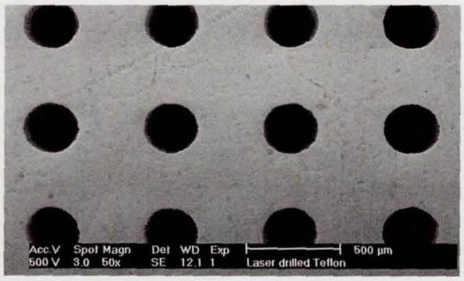
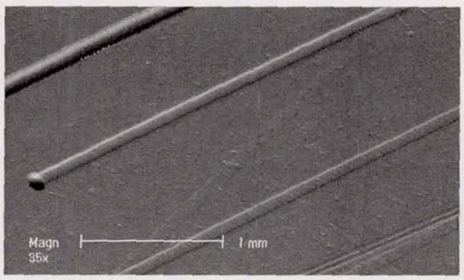
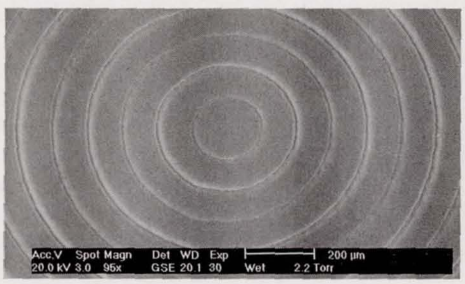


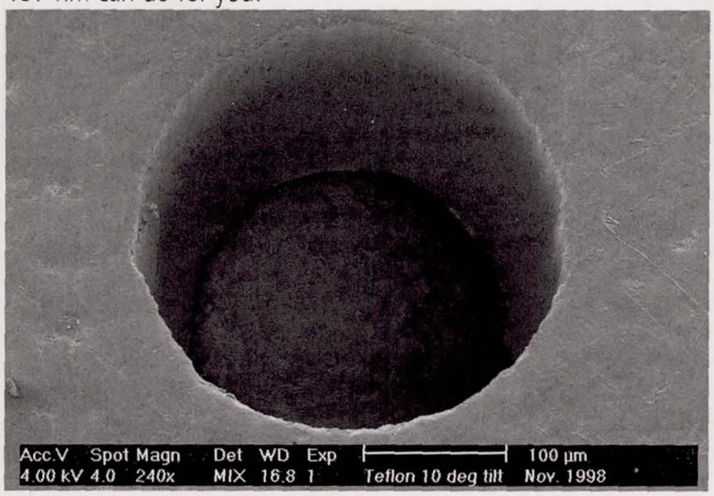
Array drilled in Teflon.



Channels etched in Teflon.



Fresnel lens in fused silica produced by focal point scribing.



Holes drilled in PTFE (Teflon) using a contact mask.

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capability to system and plant operators. To enable the use of low-cost fiber optic technology, point-to-point serial communications links connect the relays to a communications processor, forming a star topology network. At many sites, the relays, FiberWire, and a communications processor hub make up the entire I&C system; at other sites, they are a subsystem of a larger I&C complex.

Figure 1 shows a block diagram of a protection, monitoring, and control system, typical of the thousands of substations that use SEL relays, communications processors, and transceivers with Lucent's FiberWire. These links are the mechanism to retrieve data from the relays, and provide direct control and instructions to the relays. It is useful to have the internal relay clocks synchronized, so that time-tagged reports from different relays can be analyzed in the proper time sequence. Each link between a relay and a communications processor uses two optical fibers; each FiberWire pair offers full-duplex serial communications. A unique patented mechanism in SEL-2810 fiber optic transceivers uses one of the same fibers to send an IRIG-B time synchronization signal from the communications processor to the relay, so that all of the internal clocks in the station are synchronized to within a few milliseconds. One FiberWire cable to each relay adds to this a full-duplex link for real-time data and control, and virtual terminal report retrieval and interaction.

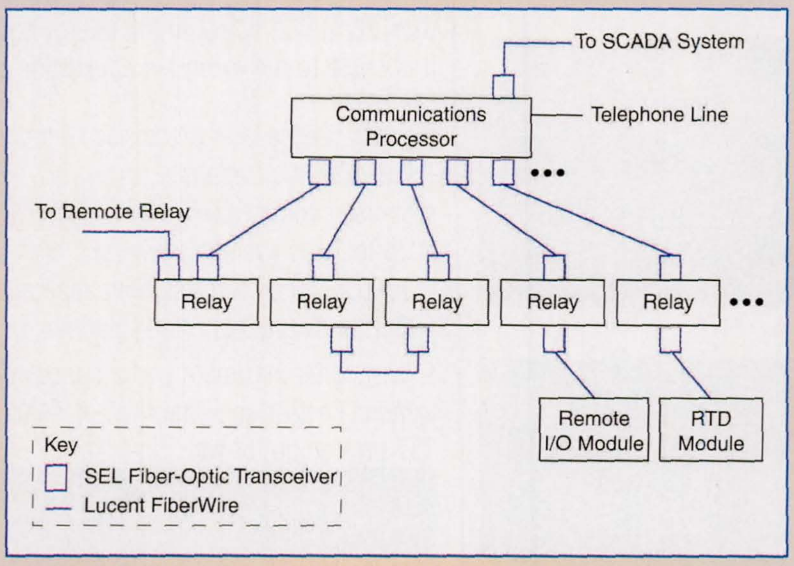


Figure 1. Station protection, instrumentation, and control system block diagram.

Protecting Motors and Power Lines

Electric motor manufacturers embed resistance temperature detectors (RTDs) in their motors to sense the temperature of the electrical windings. An SEL RTD module, which connects to RTDs at the motor, has a built-in fiber optic port to connect to an SEL motor-protection relay using a simplex FiberWire cable. If the insulation of the motor winding fails, damaging currents can flow through the RTD wiring. The FiberWire link insulates the SEL relay and the rest of the protection and control system from the RTD wiring. The relay also has valuable monitoring and reporting functions to help prevent process outages because of motor failures. Often, too, the motor relays are connected to an I&C system with FiberWire.

Relays perform most of their protective functions as autonomous devices. Some protection schemes, however, use communications between relays to rapidly discriminate whether a fault is in each relay's zone of protection, to increase sensitivity, or to coordinate tripping or blocking with the other end of a line or an adjacent line. SEL uses patented Mirrored Bits™ communications between relays and other devices for high-speed power line protection and restoration. Inside substations, SEL customers typically use V-system technology and dedicated FiberWire. Between substations, they usually use FiberWire's crimp and cleave ST connectors to mate with patch-panels for multifiber cables.

Easy to Use

SEL makes it at least as easy for customers to use fiber as to use copper. The SEL transceivers are powered by pins in the EIA-232 connector and are close to the size of a cable connector shell. In a standard 9-pin serial port connector, you can use the request-to-send (RTS) pin as a power pin instead of a hardware-handshake line by setting the software to hold it in a "high" state. SEL sells prepackaged EIA-232 cables that include the transceiver and terminated FiberWire. You can just connect it like a copper EIA-232 cable, and experience all of the EMI immunity and isolation advantages of fiber.

The SEL transceivers were designed for harsh environments, but their application is not limited to electrical power uses. For example, an observatory uses SEL transceivers for the link to a weather instrumentation site. Along with extending the distance beyond the EIA-232 copper length limitation, this FiberWire link eliminates concern about lightning or signal ground loops. The broad temperature range of the transceivers and fiber cables makes them ideal for this application.

Protective relays and other devices must function for years in severe environments. There are compelling reasons for communicating with each device, both as a component of a larger I&C system and to support standalone functions. The technologies of Lucent's FiberWire products and SEL transceivers yield all of the advantages already described, plus the following compared to other fiber options:

- The transceivers require no separate power supply or mounting; they connect directly to the serial port connector and use power from the EIA-232 port;
- Complete, preterminated, ready-to-use EIA-232 cables include transceivers and FiberWire;
- The quick and easy 200-micrometer FiberWire termination uses Lucent crimp and cleave V-pins or ST connectors and termination tools, for installations where field termination is preferred; it takes far less time to terminate a duplex FiberWire cable than it does a six-wire EIA-232 copper cable;
- The V-System models use visible light (650 nm) for easy inspection;
- The SEL transceivers and FiberWire cost less than other fiber alternatives.

Fiber optic technology overcomes many severe conditions in electrical stations, improves personnel safety, and provides more reliable, lower-noise communications. Lucent's crimp and cleave termination tools eliminate special training and polishing, so it is easier to terminate FiberWire than copper. SEL transceivers and complete cables further simplify using fiber optics in power stations and other applications.

For more information about SEL, contact Gary Scheer at Schweitzer Engineering Laboratories, 2350 N.E. Hopkins Ct., Pullman, WA 99163; (509) 336-4429; e-mail: fiberoptic@selinc.com. Readers can also visit the SEL web site at www.selinc.com. For more information about Lucent's FiberWire, contact Lucent at 55 Darling Dr., Avon, CT 06001; (860) 678-0371; e-mail: info@fiber-wire.com; www.fiber-wire.com.

PHOTONICS *file*

Recent photonics briefs published in NASA Tech Briefs

Many photonics-related briefs from NASA's field center laboratories appear in *NASA Tech Briefs* rather than in the *Photonics Tech Briefs* supplement. Listed here are some from issues of *NASA Tech Briefs* just past, edited for brevity and indexed with reference to original publication and the availability of a Technical Support Package on *Photonics Tech Briefs'* web site.

NASA Tech Briefs August 2000, page 50

Microfabricated High-*Q* Optical Resonators for Microphotonics *(NPO-20604)*

Submillimeter-sized, transparent, solid, truncated spheres and ellipsoids for use as optical resonators in integrated microphotonic devices would be made by microfabrication techniques like those used in the electronics industry to make integrated circuits. Heretofore, microspheres have been fabricated manually, in small numbers, for use in laboratory experiments. The proposal by the Jet Propulsion Laboratory team regarding adaptation of microfabrication techniques is prompted by a desire to obtain mass-producibility of such resonators with reproducibility of design, plus a capability for integration of the resonators with other photonic devices. The finished resonator would have an ellipsoidal surface near the plane of symmetry. Because of the nearly Gaussian falloff of the whispering-gallery modes away from their localization near the symmetry plane, the truncated ellipsoid would be electromagnetically indistinguishable from a full ellipsoid.

For further information, access the Technical Support Package (TSP) ***free on-line at www.ptbmagazine.com*** *under the Physical Sciences category.*

NASA Tech Briefs September 2000, page 46

Algorithm for Calibrating an Imaging Interferometer *(ARC-14054)*

An algorithm has been devised to greatly simplify and improve the calibration and the reduction of systematic noise of an imaging interferometer or other similar interferometric instrument. The algorithm makes it unnecessary to illuminate the detector uniformly or to perform difficult and time-consuming laboratory calibration, disassembly, and reassembly procedures. Calibration information can be extracted from ordinary images—even from highly variable scenes. With this algorithm calibration can be performed with much more flexibility—in the laboratory or in the field. Moreover, the algorithm makes it possible to calibrate the instrument in nearly real time—immediately before or after the acquisition of interferometric images—so that one can have some assurance that there has not been enough time for vibrations and other environmental factors to affect the calibration significantly. The algorithm has been implemented in prototype software that includes parts in Interactive Data Language (IDL) together with a comprehensive set of routines for processing imaging-interferometer-type data.

For further information, access the Technical Support Package (TSP) ***free on-line at www.ptbmagazine.com*** *under the Test and Measurement category.*

NASA Tech Briefs September 2000, page 67

Solitons on WDM Beams in a Nonlinear Optical Fiber *(NPO-20772)*

A paper from NASA's Jet Propulsion Laboratory sets the ultimate limit on the maximum amount of optical data pulses that can be sent through a single fiber in a given period under the wavelength-division-multiplexed (WDM) format. The discovery in 1973 that optical solitons on a single wavelength beam can exist in fiber is one of the most significant events since the perfection of low-loss optical communications. This means that, in principle, data pulses may be transmitted in a fiber without degradation forever. Another significant event is the development of WDM transmission in a single-mode fiber. This means that multiple beams of different wavelengths, each carrying its own data load, can propagate simultaneously in a single-mode fiber. But when such beams co-propagate in a single-mode fiber, such as in the WDM case, interaction of pulses on different beams via the nonlinear cross-phase-modulation effect (the Kerr effect) is usually instrumental in destroying the integrity of solitons. This paper shows that temporal solitons can exist on WDM beams in a single fiber under appropriate conditions.

To obtain a copy of the report, "The Existence of Optical Solitons on Wavelength Division Multiplexed Beams in a Nonlinear Fiber," access the Technical Support Package (TSP) ***free on-line at www.ptbmagazine.com*** *under the Physical Sciences category.*

Phonon-Assisted Quantum-Well Infrared Photodetector

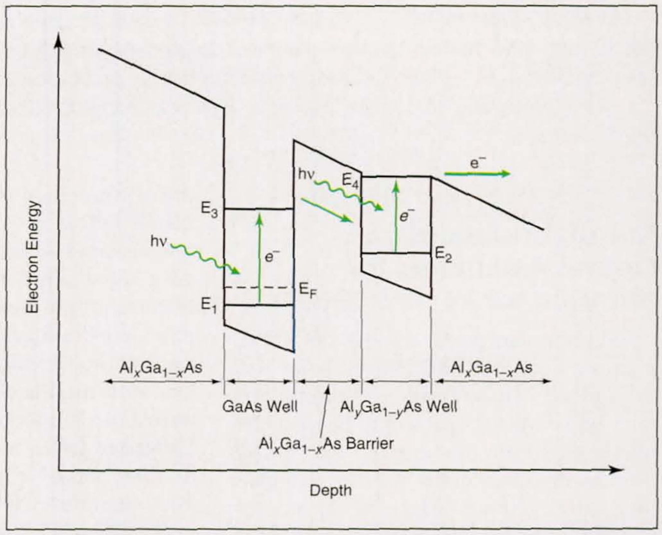
Dark current would be reduced by a unique dual-quantum-well structure.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed quantum-well infrared photodetector (QWIP) would exploit resonant-phonon-assisted transitions to reduce dark current significantly below that of a typical previously developed QWIP operating at the same wavelength and temperature. The reduction in dark current would translate to greater sensitivity, a capability to measure the diminished infrared radiation from cooler objects, and/or a less severe requirement for cooling an infrared sensor to obtain a desired signal-to-noise ratio.

The proposed QWIP would likely be fabricated by molecular-beam epitaxy of alternating layers of doped GaAs and $Al_xGa_{1-x}As$ on a semi-insulating GaAs substrate. The thicknesses and compositions of the GaAs and $Al_xGa_{1-x}As$ layers would be chosen to form a stack of 25 pairs of coupled quantum wells. The depths and thicknesses of the wells, the thickness of the barrier between the wells in each pair, and the bias electric field to be applied during operation would be chosen to (1) promote excitation of electrons through absorption of photons in the infrared wavelength range of interest and (2) increase (relative to previously developed QWIPs) the heights of the energy barriers to thermionic emission, which is the dominant source of dark current in the temperature range of interest (≤55 K).

The figure is a conduction-band energy diagram of one pair of quantum wells. The wells would be engineered so that at the threshold applied electric field, $E_2 – E_1 = \Delta E_{hk}$, where ΔE_{hk} is an optical-phonon energy. Barrier heights and well thicknesses would be chosen such that the photoexcitation energy between ground and first excited states in both wells would be the same; that is, $E_3 – E_1 = E_4 – E_2 = \Delta E_{hv}$, where ΔE_{hv} is the photoexcitation energy (photon energy) at the desired wavelength of peak detector response. In addition, E_4 — the first excited state of the right well — would be placed exactly at the top of the well.



The **Energy Levels in the Two Quantum Wells** and the barrier between them would be chosen to impose high barriers against thermionic emission and thermionic tunneling, without hindering the escape of photoexcited electrons from the right well to the continuum. The wavy lines represent the absorption of photons.

The ground state of the left quantum well would be doped up to Fermi level E_F, which would be below E_2. Electrons in the E_1 level would become excited to the E_3 level by absorbing photons. The stated engineered relationships among the energy levels at the threshold electric field would give rise to resonance between (1) the transition from E_3 to E_2 and (2) the optical phonon without (3) transfer of momentum. Consequently, an electron that had been photoexcited from E_1 to E_3 would make a rapid transition (within a typical quantum-state lifetime of the order of a picosecond) from E_3 to E_2. Repeated such excitations and transitions would cause the ground (E_2) state of the right potential well to become populated.

The lifetime of the E_2 level would exceed that of the E_3 level because decay back to E_1 would involve emission of an optical phonon with a large transfer of momentum. The lifetime of the E_2 level would be long enough that an electron in that level would have a high probability of absorbing a second photon, thereby gaining enough energy to escape from the right well to be collected as photocharge. Optimization of design would involve balancing of these various quantum transition processes while providing for coupling of radiation of the wavelength of interest to electrons in the quantum wells.

The quantum efficiency of the proposed QWIP would be about half or even less than half of that of a typical previously developed QWIP, because now two photons would have to be absorbed to get one electron out. However, there would still be a net increase in signal-to-noise ratio because effective height of the barrier against thermionic emission would be increased sufficiently that the dark current would be reduced to much less than half of the previous value. For example, it has been estimated that for a wavelength of 15 μm (equivalent to a photon energy of about 82 meV), an opti-

cal-phonon energy of about 36 meV, and a temperature of 55 K, the dark current of the proposed QWIP would be about a thousandth of that a typical previously developed QWIP.

This work was done by Sumith Bandara, Sarath Gunapala, and John K. Liu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

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Refer to NPO-20568, volume and number of this NASA Tech Briefs *issue, and the page number.*

Whispering-Gallery-Mode Microspheres as Light Modulators

Ultrahigh modulation efficiency could be achieved.

NASA's Jet Propulsion Laboratory, Pasadena, California

Light modulators of a proposed type would exploit the propagation of light in "whispering-gallery" electromagnetic modes in microspheres made of electro-optical materials. These modulators would offer advantages of ultrahigh modulation efficiency and increased bandwidth, relative to their nearest competitors, which are traveling-wave electro-optical modulators. The introduction of the proposed modulators could increase the bandwidths and reduce the power demands of a variety of both free-space and guided-wave communication, sensing, and signal-processing systems that utilize radio-frequency (typically, microwave) modulation of optical carrier signals.

The whispering-gallery modes of a dielectric microsphere are resonance modes in which electromagnetic fields are confined, by internal reflection, to an interior region within about 10 μm of the surface of the sphere. For a microsphere with a diameter ≥ 10 μm, the dimension of the resonator is much larger than the wavelength of light. Thus, the loss due to the finite curvature of the resonator is negligible, resulting in a resonance quality factor (Q) that is high and is limited mainly by the attenuation of the light in the dielectric material.

An important example is that of a microsphere with a diameter of about 3 mm, made of the electro-optical material lithium niobate. Such a microsphere can support optical whispering-gallery modes at $Q \approx 107$. Because its relative permittivity at radio frequencies is about 50, it can also support microwave and millimeter-wave whispering-gallery modes at $Q \approx 104$. These characteristics are favorable for use of the microsphere as a radio-frequency light modulator:

In the proposed modulation scheme, one would apply a radio-frequency

(microwave or millimeter-wave) field to a microsphere in which an optical signal propagates in a whispering-gallery-mode. Acting via the electro-optical effect, the electric component of the radio-frequency field would alter the speed of propagation of, and thereby modulate, the optical signal. With a proper choice of design parameters, the radio-frequency field could be concentrated in a whispering-gallery mode in the same near-surface interior region as that of the optical whispering-gallery mode. Because of the high Q values, the circumferential path along which the radio-frequency and optical fields would propagate and interact via the electro-optical effect would be > 1 km long; in contrast, the interaction lengths in typical traveling-wave electro-optical modulators range from a few millimeters to a centimeter.

The increase in the effective interaction length would reduce the change in index of refraction needed to obtain a given depth of modulation in a microsphere electro-optical modulator to about 10^{-6} that needed to obtain the same depth of modulation in a traveling-wave electro-optical modulator. The net effect is that the order of magnitude of modulation potentials for microsphere electro-optical modulators would be millivolts, as compared with volts for traveling-wave electro-optical modulators. Even after accounting for inefficiencies in the coupling of optical and radio signals between a microsphere and the other optical and electronic components, microsphere electro-optical modulators are expected to be orders of magnitude more efficient than are traveling-wave electro-optical modulators. Moreover, it has been estimated that the maximum useable modulation frequency would be increased from ≈50 GHz in the traveling-wave case to ≈100 GHz in the microsphere case.

This work was done by Lute Maleki, Anthony F. J. Levi, X. Steve Yao, and Vladimir Iltchenko of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

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Refer to NPO-20664, volume and number of this NASA Tech Briefs *issue, and the page number.*

Coupling Light Between Optical Fibers and Noncircular Beams

Cylindrical lenses are used to change aspect ratios.

NASA's Jet Propulsion Laboratory, Pasadena, California

Cylindrical lenses can be used to increase the efficiency of coupling of light between (1) beams with circular or nearly circular cross sections propagating in single-mode optical fibers and (2) free-space beams with noncircular cross sections and with different radii of curvature of wavefronts on mutually perpendicular meridional planes. Beams of the second type are generated by semiconductor optoelectronic devices (e.g., diode lasers and amplifiers) that contain stripe waveguides; the waist-cross-section aspect ratios of such beams can be as large as 3:1.

Heretofore, it has been common practice to use anamorphic prism pairs to change aspect ratios of light beams entering and leaving single-mode optical fibers. It is also possible, in principle, to change beam aspect ratios by use of cylindrical

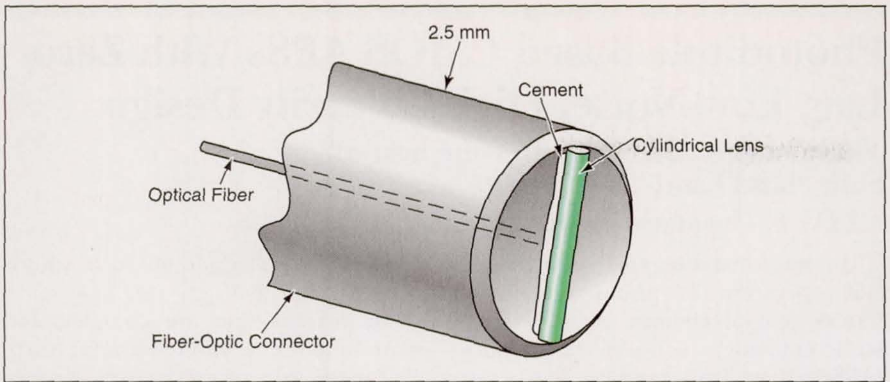

Figure 1. A **Cylindrical Lens** is cemented to the end faces of a fiber-optic connector and the fiber held by the connector.

lenses mounted within diode laser packages. Both of these approaches entail disadvantages: Anamorphic prism pairs are bulky and introduce insertion losses of about 10 percent, and it is often not practical to modify diode laser packages to incorporate cylindrical lenses. However, it is practical to mount cylindrical lenses on the ends of optical fibers.

The cylindrical lens for a typical application is made of a suitable glass and is designed to be glued to the end face of a connector that holds the optical fiber (see Figure 1) by use of an ultraviolet-curable cement that matches the index of refraction of the fiber, the lens, or both. In conjunction with the indices of refraction of the fiber and lens glasses, the diameter of the lens and its nominal small distance from the end face of the fiber are chosen to obtain the required conversion of wavefront curvature in the affected plane. The design provides that any gap between the lens and the end face of the fiber be filled with the cement.

In preparation for mounting the cylindrical lens on the end of the fiber, light of the wavelength of interest is coupled into the fiber at one end and a video camera sensitive to light at that wavelength is positioned to obtain a cross-sectional image of the beam of light emerging from the end of the fiber. The cylindrical lens is placed on a three-dimensional translation stage and moved to approximately the desired position near the end of the fiber. The gap between the cylindrical lens and the end face of the fiber is filled with cement, but not with so much that the cement could overflow and cover the free-space side of the lens. Then by use of the translation stage, the lens is maneuvered precisely into position on or near the end face of the optical fiber. The maneuvers are continued until the image exhibits the required aspect ratio and is centered on the optical axis of the fiber (see Figure 2). Then ultraviolet light is applied to cure the adhesive in place.

This work was done by Herbert Pickett and Christopher Mackay of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

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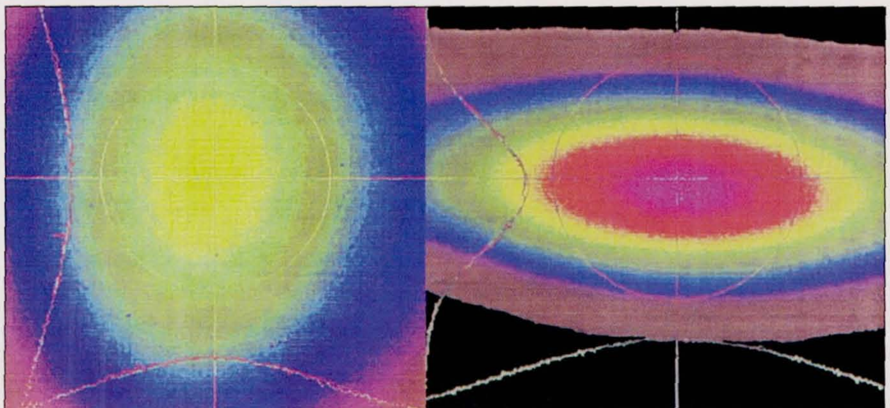

Figure 2. **These Are Cross-Sectional Images of Light Beams** at a wavelength of 852 nm emerging from the end of a polarization-maintaining optical fiber of aspect ratio 0.8, without and with a cylindrical lens. The lens converted the aspect ratio to 2.9. The insertion loss in the presence of the lens was only 3 percent.

Photodiode-Based CMOS APSs With Zero-Lag, Low-Noise, High-Linearity Design

These image detectors offer the best of both "hard" and "soft" reset.

NASA's Jet Propulsion Laboratory, Pasadena, California

Two improved schemes for the design and operation of photodiode-based CMOS (complementary metal oxide/semiconductor) active-pixel sensors (APSs) afford zero image lag, low noise, and high linearity of response even under low illumination. Figure 1 schematically depicts the circuitry for one pixel according to a typical older scheme. In soft reset, the sensing node does not charge up to the power-supply potential (V_{DD}), and depends strongly on the potential at the beginning of the reset. In hard reset, the sensing node charges up to a known potential, usually V_{DD}.

For reasons that are complex and must therefore be omitted from this article for the sake of brevity, typical older soft- and hard-reset schemes entail disadvantages and advantages as follows:

- Soft reset advantageously results in low-noise output and a high power-supply rejection ratio (PSRR). However, disadvantageously, soft reset results in image lag of as much as 70 percent of the mean signal in the pre-

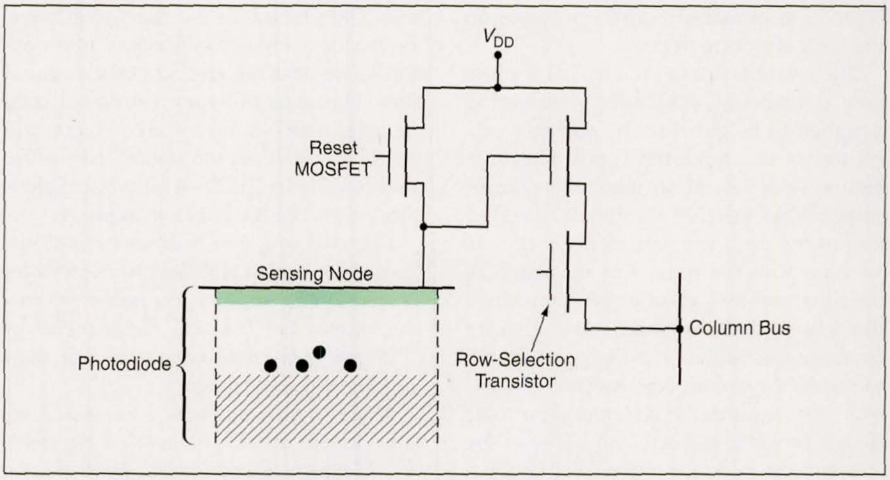

Figure 1. A **Typical Prior CMOS APS Circuit** is designed and operated according to a soft- or a hard-reset scheme. Both schemes entail advantages and disadvantages.

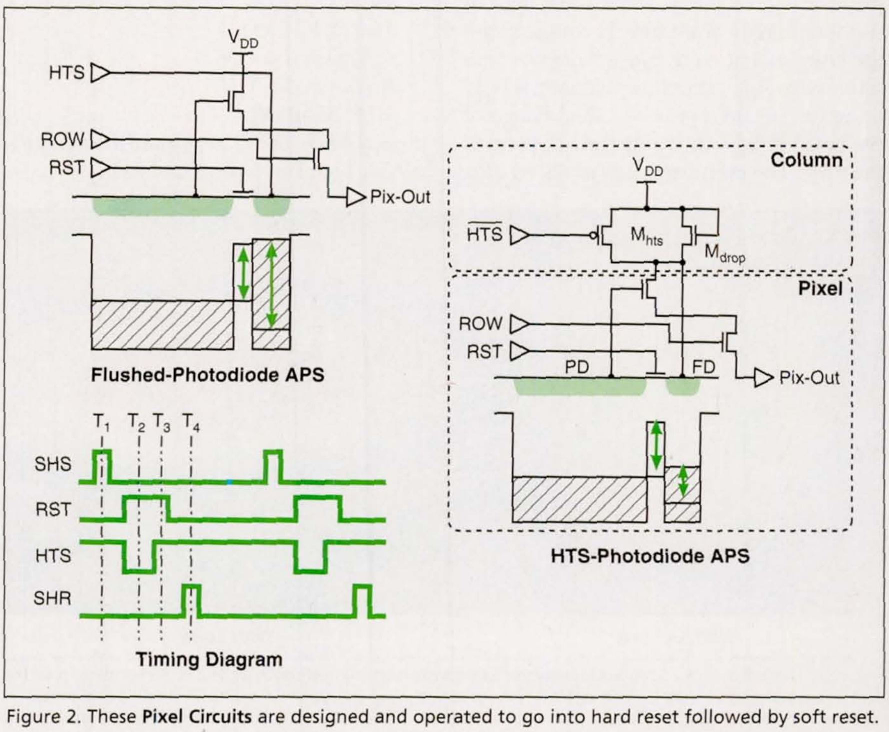

Figure 2. These **Pixel Circuits** are designed and operated to go into hard reset followed by soft reset.

vious frame, and a markedly nonlinear response under low illumination.

- Hard reset advantageously eliminates image lag but disadvantageously results in increased read noise, dark current, and reduced power-supply ratio.

Under the improved schemes, the disadvantages are eliminated by resetting pixels first by hard reset and then by soft reset. Hard reset erases the memory from the previous frame, eliminating image lag and nonlinearity, while soft reset allows operation with low-read noise. Thus, low noise, zero image lag, and high linearity are achieved simultaneously.

Figure 2 illustrates the pixel circuits that are used for implementation of the two new schemes, which are characterized by the terms "flushed photodiode" and "hard-to-soft (HTS) reset photodiode," respectively. In the flushed-photodiode APS, the pixel circuit contains an additional line (denoted "HTS") for a row-decoded signal that controls the potential at the drain of the reset MOSFET (metal oxide/semiconductor field-effect transistor). Pulsing HTS reduces the drain potential, allowing the pixel to be reset in hard reset mode. In the HTS APS, no change in the pixel design is necessary. In this scheme, V_{DD} is routed to each column through an n- and a p-channel MOSFET. The gate of the p-channel MOSFET is connected to a line (denoted "HTS") that carries a column-decoded signal. Pulsing HTS momentarily high during the reset phase causes the source of the reset MOSFET to reduce below V_{DD}, causing the pixel to go into hard reset. The hard-reset level is determined by the size of the n-channel MOSFET, and is set to approximately $V_{DD}/2$. In both schemes, soft reset of the pixel following the hard reset is achieved once the HTS pulse goes low.

This work was done by Bedabrata Pain, Guang Yang, Thomas Cunningham, and Bruce Hancock of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at*** ***www.nasatech.com*** *under the Electronic Components and Systems category.*

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Refer to NPO-20716, volume and number of this NASA Tech Briefs *issue, and the page number.*

Improved Illumination Device for Inspecting Window Surfaces

Efficiency of coupling is increased and stray light is reduced.

John F. Kennedy Space Center, Florida

A fiber-optic illumination device that aids the inspection of window surfaces has been improved to make it suitable for automated detection of pits, scratches, and subsurface damage by use of a machine-vision and image-analysis system. The improvements, which include modifications in both the optical and mechanical aspects of its design, significantly reduce the brightness of stray light that, previously, was bright enough to interfere with automated detection of defects.

The previous version of the device (see Figure 1) was described in "Illumination Device for Inspecting Window Surfaces," *NASA Tech Briefs*, Vol. 22, No. 11 (November 1998), page 68. The device could be temporarily attached to a window by use of suction cups. The device coupled light from a fiber-optic cable, through a block of clear material, into the window pane to create a side-lighting effect. One advantage of this or a similar lighting scheme is that light remains within the window because of total internal reflection, except at sites of surface or subsurface defects. Hence, the defects appear bright on an otherwise dark window surface and could be readily observed. Another advantage of this lighting scheme is its selectivity: The more important deep defects present larger cross sections to side illumination than do shallow defects of the same lateral dimensions and therefore tend to appear brighter. Furthermore, dirt particles on the surface, which do not constitute defects in the window and are thus unimportant for purposes of this type of inspection, may couple some light out of the window but they also shield the observer from this light. Hence dirt tends to appear dim, and the incidence of false detections of defects is lower than it would be if a different lighting scheme were used.

A human inspector can distinguish between foreground and background light by, among other actions, refocusing at different depths and changing the angle of observation; however, an automated defect-detection system cannot do this. Therefore, to ensure high sensitivity and consistent performance in an automated defect-detection system, it is necessary to minimize background light, including stray light generated by the illumination device.

The previous version of the illumination device generated appreciable stray light because of two weaknesses in its design. The first weakness was that a significant fraction of light was not subject to total internal reflection in the window. The second weakness was that a significant amount of light was scattered by partial reflection at (1) the interface between the acrylic block and the window and (2) the end of the fiber-optic light guide and the adjacent poor-optical-quality surface at the bottom of the light-guide hole in the acrylic block.

The improved design overcomes these weaknesses. The acrylic block of the previous design is replaced with a triangular prism (see Figure 2) that is shaped and dimensioned to minimize undesired scattering and maximize the amount of light subject to total internal reflection. Light from the fiber-optic light guide enters the prism through the smallest prism face, which is nearly perpendicular to the win-

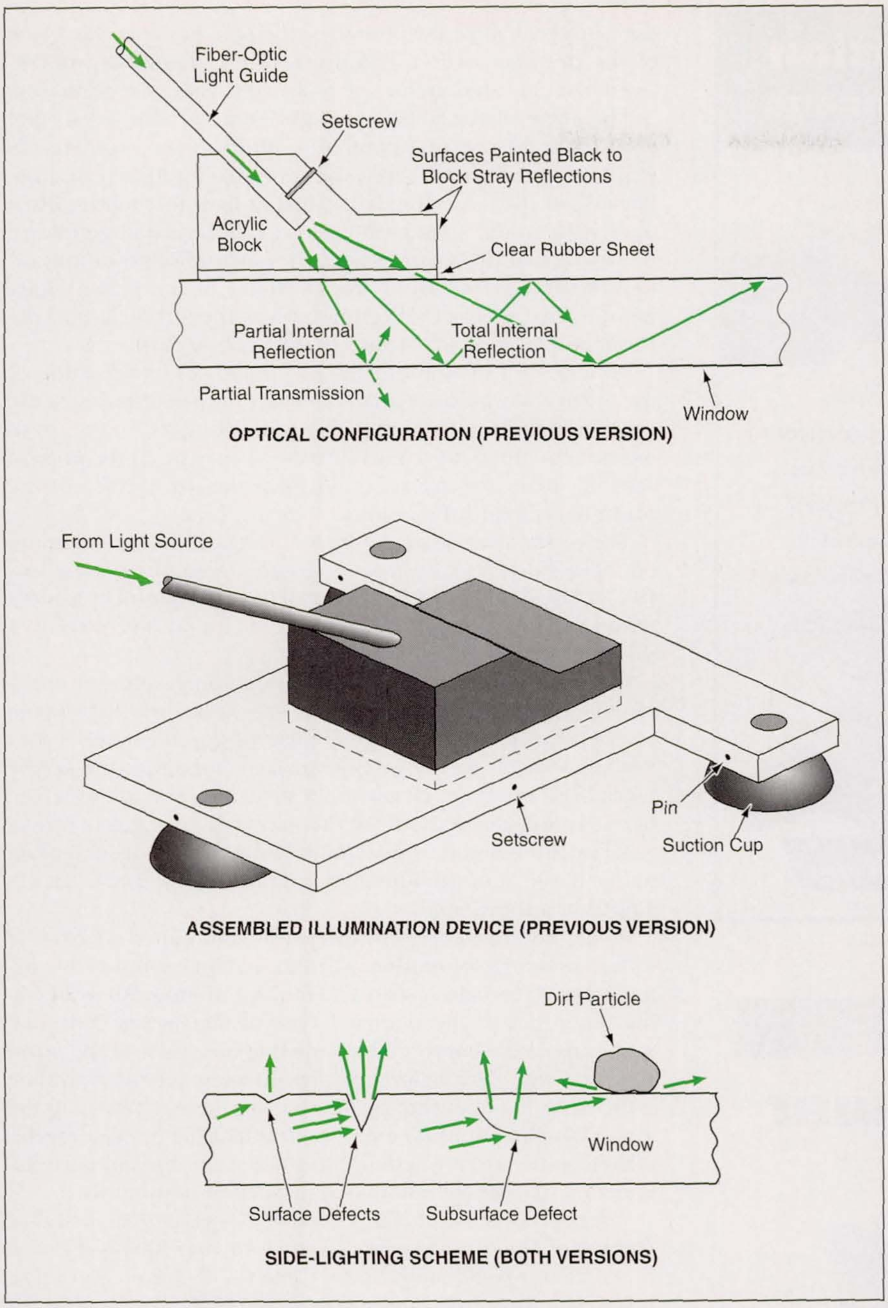

Figure 1. The **Previous Version of the Device** *created the same desired side-lighting effect as does the present version. However, the previous version generated too much stray light to be useful for automated detection of defects.*

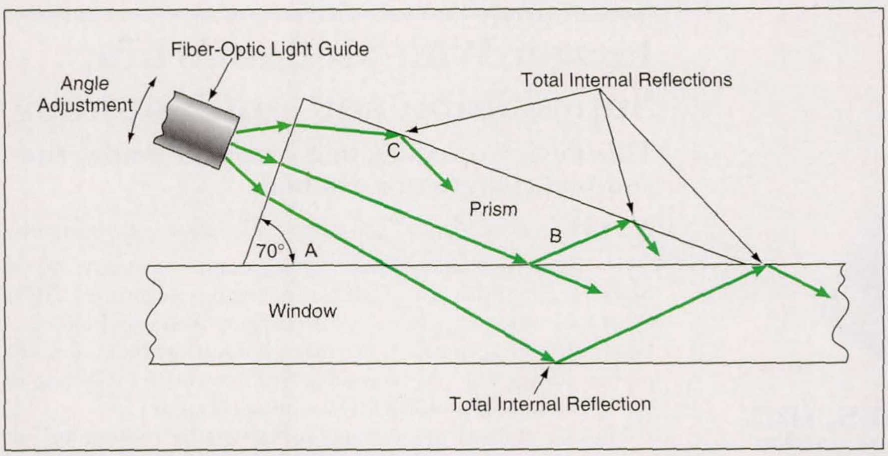

Figure 2. The **Improved Optical Layout** of the present design increases the amount of light coupled into the window and reduces the amount of stray light.

dow surface. Unlike the bottom of the hole in the acrylic block of the previous version, this prism face is accessible prior to assembly, and can therefore be polished to minimize scattering.

The angle of the fiber-optic light guide is adjusted so that even the light rays that enter the window pane most steeply (e.g., ray A in Figure 2) are subject to total internal reflection. Because of the large angular spread of light leaving the fiber-optic light guide, some rays (e.g., ray C in Figure 2) go toward the surface of the prism, where they are reflected downward toward the window pane. Proper choice of the prism angles ensures total internal reflection both at the top surface of the prism and the bottom surface of the window pane.

Because of a small mismatch of the indices of refraction of the prism and window, a small fraction of rays is reflected at the prism/window interface (e.g., ray B in Figure 2). In the previous version, these rays contributed to stray light. In the present version, these rays are reflected from the top surface of the prism back toward the window.

The prism must be made short enough to prevent coupling out of rays that have been reflected once from the bottom surface of the window. The maximum length permitted by this criterion depends on the thickness and the index of refraction of the window.

Going beyond purely optical considerations, another disadvantage of the previous version of the device was that as the suction cups gradually relaxed, a gap of approximately 1 mm developed between the window surface and either the acrylic block or (if used) the clear rubber sheet attached to the acrylic block. It was necessary to fill the gap with an index-of-refraction-matching liquid, which could easily run out or evaporate under the heat of the illumination, making the device unreliable after a short time.

In the improved version, the prism is mounted in a frame with a free range of motion, >1 mm, that makes it possible for the prism to remain in contact with the window. After attaching the device to the window by use of the suction cups, one pushes specially shaped wedge slides between parts of the prism and the frame. This action stretches the suction cups, providing sufficient force to ensure steady contact, thereby retarding the loss of coupling fluid. The net result is that the device provides reliable and constant lighting with minimum background illumination suitable for automated inspection of windows.

This work was done by Henry Weidner, Terry Greenfield, and Carl Hallberg of Dynacs Engineering Co. and Anthony Kraljic of United Space Alliance for **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.* KSC-12127

Imager With Motion-Artifact Suppression and Antiblooming

This device operates in a snapshot mode, and residual charges are drained.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved photodiode-based complementary metal oxide/semiconductor (CMOS) active-pixel sensor (APS) incorporates features to (1) allow imaging with very high electronic shutter speeds, (2) suppress motion artifacts, and (3) prevent image lag and blooming (the spread of image lag to the area adjacent to a brightly illuminated area).

- Motion artifacts are distortions caused by motion in the scene imaged on a sensor. Ordinarily, a CMOS imager of older design is operated in a rolling-shutter mode, in which

each row of pixels is exposed at a different instant of time. The rolling-shutter mode introduces distortion into the image; for example, if the scene contains an object moving in the direction of the row exposure sequence, then in the output image, the object appears elongated in the direction of motion.

- Image lag is caused by retention of partial pixel image charges from previous frames. Blooming interferes with efforts to perform high-contrast, low-light imaging.

In the improved CMOS APS, motion artifacts are suppressed by rapid electronic shuttering in a snapshot mode; all pixels are exposed simultaneously. Blooming and image lag are prevented by draining residual pixel photocharges between frames. These improvements are made possible by a unique design implemented in standard single-polysilicon CMOS.

Figure 1 is a schematic cross section of a single-pixel portion of the device. Photocharge is integrated under the photogate (PG). The integration (exposure) time is controlled by a voltage pulse applied to the PG; in general, the exposure time can be thus defined to within 10 µs in this and all other pixels.

There are two transfer gates: TX1 and TX2. The transfer gates are common to the entire CMOS APS chip and are operated by application of voltage pulses timed in conjunction with the voltage pulse applied to the PG. By virtue of fabrication in standard CMOS single-polysilicon CMOS, the gates are separated by floating n+ diffusions. TX1 is used for transferring the integrated photocharge to a sensing node for detection. TX2 serves both as an antiblooming gate and for defining exposure time. The sensing node serves as part of a frame buffer, which makes it possible to perform frame readout at any time after charge integration, independently of the charge-integration time.

Although the exposure time is defined by the duration of the pulse applied to the PG, the floating diffusions continue to collect photocharges. The transfer of these residual photocharges to the sensing node is the cause of image lag in a CMOS APS of older design. In the present CMOS APS, these charges are drained off, prior to beginning integration of charge for the next frame, by application of voltage pulses with suitable timing and levels to the PG and TX2.

Figure 2 presents some test images acquired by use of the improved CMOS APS:

- Snapshots of a fan rotating at 1,800 revolutions per minute were made

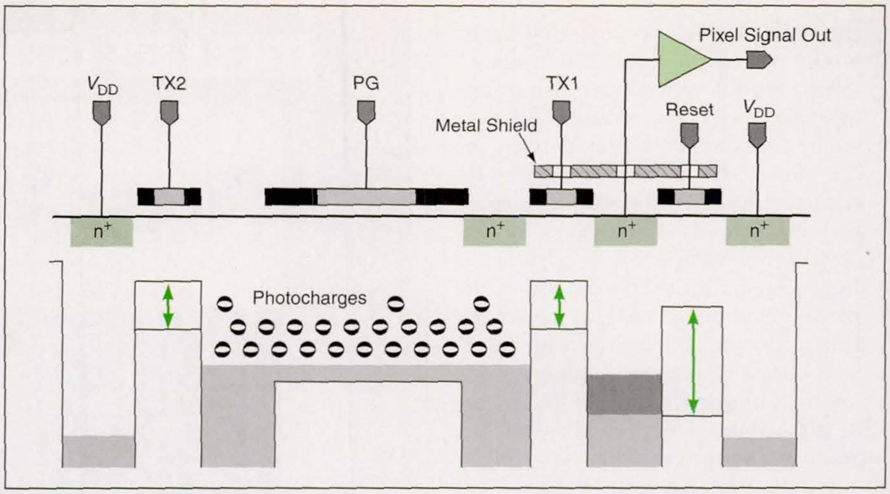

Figure 1. **Two Transfer Gates and a Photogate** are used to control the integration and detection of photocharges. TX2 acts as a lateral overflow gate and is used to drain residual charges between exposures to prevent image lag.

with 30-ms and 100-μs exposures. The 100-μs image demonstrates the ability of the device to "freeze" the motion of the fan without introducing motion artifacts.

- Images of George Washington on a dollar bill were made in two consecutive frames with illumination in during the first frame and darkness during the second one. No residual image was observed in the second frame.
- Another image of George Washington on a dollar bill was made with ordinary illumination plus spot illumination by a laser. No blooming was observed, even though the laser illumination was 80 dB above the saturation level of the device.

This work was done by Bedabrata Pain, Guang Yang, Orly Yadid-Pecht, and Chris J. Wrigley of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

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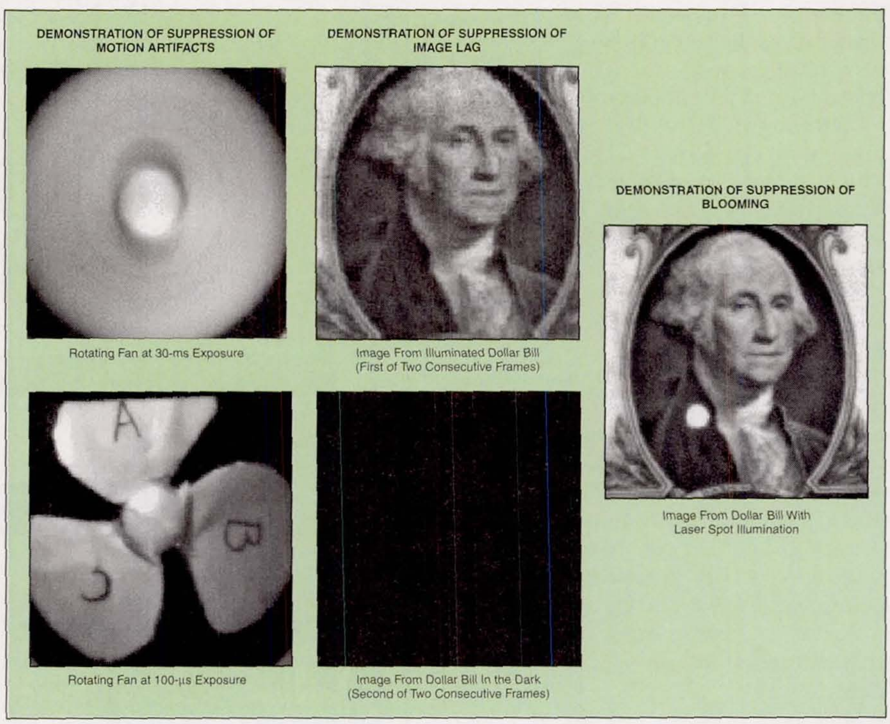


Figure 2. **These Test Images** made with the improved CMOS APS demonstrate its ability to suppress motion artifacts, image lag, and blooming.

Fast Infrared Spectrometer

This instrument could be useful in research on fires.

John H. Glenn Research Center, Cleveland, Ohio

A spectrometer has been developed for acquiring transient emission and absorption spectra in the wavelength range from 1.2 to 5.0 µm. It could be used to characterize flames, turbulence, and other transient phenomena that interact with infrared radiation. Heretofore, success in the study of such phenomena has been limited by the inability of infrared spectrometers to acquire data at sufficiently high speeds. In contrast, the present infrared spectrometer measures the spectrum at a repetition frequency of 390 Hz. The high speed of this instrument could also make it attractive for such commercial applications as monitoring food, pharmaceutical, and petroleum products in process streams and on production lines.

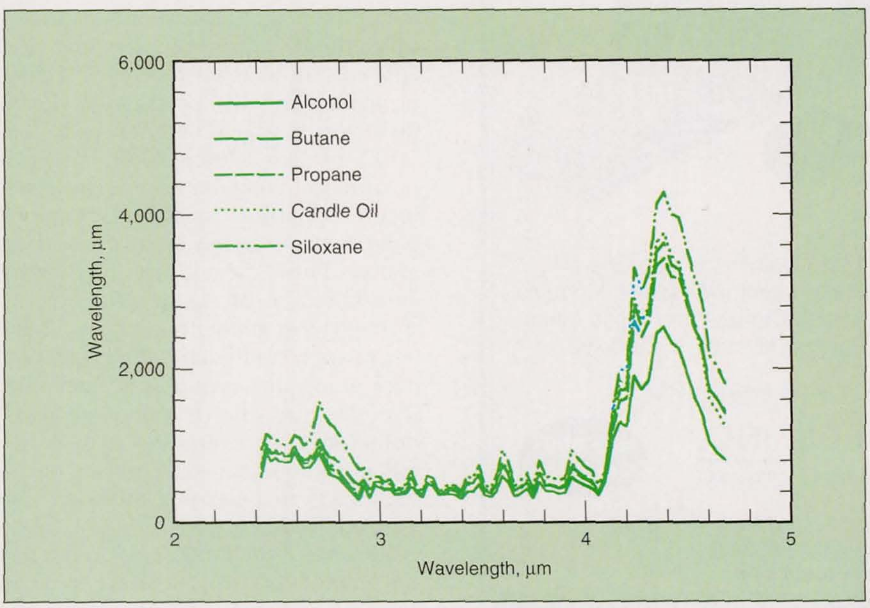
The spectrometer optics include a chopper, two prisms that serve as dispersers, and parabolic optical-path-folding mirrors. The spectrally dispersed light is projected onto a 160-pixel linear array of lead selenide photodetectors. The spectrometer also includes electronic circuitry for controlling the chopper, synchronizing readout from the pixels with the chopping cycle, and sending data to an external computer or data logger, all at the repetition frequency of 390 Hz.

The spectrometer is housed in an assembly with overall dimensions of 222 by 165 by 89 mm. A data logger for use with the spectrometer in a special application (a drop-tower rig) is mounted in a separate housing with overall dimensions of 432 by 140 by 190 mm. Because of requirements specific to that application, the data logger stores the data on an easily removable Personal Computer Memory Card International Association (PCMCIA) card. The spectrometer with the data logger is the fastest and smallest instrument of its kind.

The spectrometer was calibrated by use of a black-body radiation source at a temperature of 980 K along with narrow-pass-band filters at wavelengths of 2.56, 2.71, 4.26, and 4.33 µm. In a further calibration experiment, flames fed by alcohol, butane, propane, candle oil, and siloxane were used as radiation sources (see figure). The temperatures of the flames were calculated on the basis of the flame spectra and found to range from 2,175 K for the candle-oil flame to 2,475 K for the alcohol flame. These values are close to the expected adiabatic flame temperatures, and the fact that the lowest temperature was that of the candle flame is consistent with the expectation that the radiative loss from that flame would be greater than from the other flames. Therefore, the calculated temperatures seem reasonable.

This work was done by Yudaya Sivathanu and Rony Joseph of En'Urga Inc. for **Glenn Research Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16784.



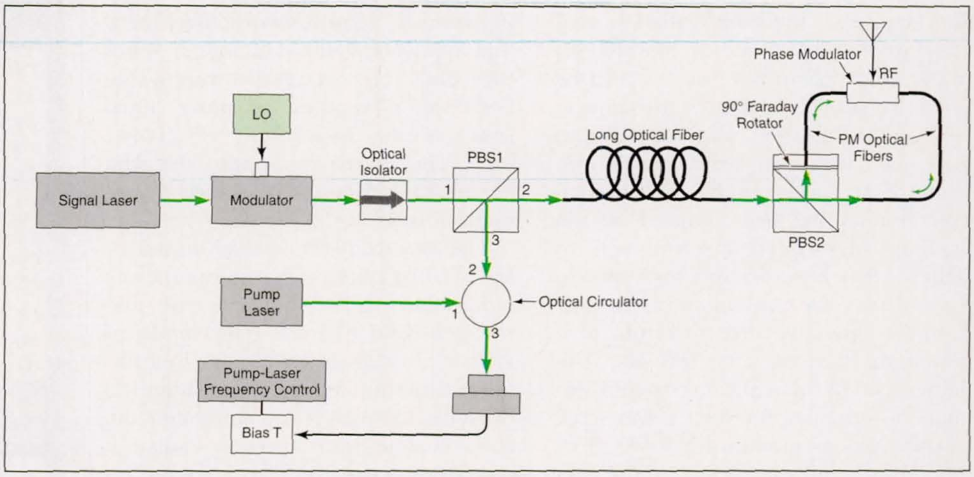
Spectra From Five Flames were measured by the fast infrared spectrometer.

Frequency-Converting Photonic Link With BSSA Amplification

Undesired polarization and dispersion effects are suppressed.

NASA's Jet Propulsion Laboratory, Pasadena, California

A photonic system has been devised for acquiring a radio-frequency (RF) signal from a remote receiving antenna via a long optical fiber. The system performs multiple functions, including upward or downward frequency conversion, optical amplification [more specifically, Brillouin selective sideband amplification (BSSA)] in the long optical fiber, and other functions, the combined effects of which are to eliminate sensitivity to polarization and to minimize signal fading caused by dispersion in the long optical fiber. The basic design of the system also makes it possible to use phase modulators. In comparison with amplitude modulators, phase modulators exhibit lower losses and cost less; moreover, unlike amplitude modulators, phase modulators do not require bias and thus do not present any bias-stabilization problems in design and operation.



This **Photonic Link** effects frequency conversion and Brillouin amplification, is insensitive to polarization, and is immune to signal fading caused by dispersion.

The system (see figure) includes a signal laser, which generates an optical carrier signal. An electronic or optoelectronic local oscillator (LO) generates a stable and spectrally pure RF subcarrier signal (typically at a frequency of 10 GHz) for use in frequency conversion. This subcarrier signal is used to modulate the optical carrier signal. (Phase modulation is preferable to amplitude modulation for the reasons stated above.) The modulated optical signal is then injected, via an optical isolator and a first polarizing beam splitter (PBS1), into the long optical fiber for propagation to the remote antenna site. This is a standard single-mode optical fiber and is typically several kilometers long.

After propagation to the remote antenna site, the polarization of the modulated carrier signal is no longer linear, and it varies when the fiber is disturbed. A second polarizing beam splitter (PBS2) separates the two polarization components, and the polarization of one of these components is modified by a 90° Faraday rotator that is incorporated into PBS2. Polarization-maintaining (PM) optical fibers are used to connect the two output ports of PBS2 to opposite ends of a phase modulator, to which the RF signal from the antenna is applied. The slow axis of each PM fiber is aligned with the polarization of the PBS2 port to which it is connected. As a result of this arrangement, the two polarization components are converted to two oppositely travelling, identically polarized light beams in the phase modulator. These beams are modulated equally by the RF signal. After passing through the phase modulator, these beams are recombined by PBS2 and sent back along the long optical fiber. The net effect of this ring-arrangement/polarization-conversion/modulation scheme is to eliminate sensitivity of the modulator to polarizing effects in the long optical fiber.

Because of the 90° Faraday rotator in the modulator ring, at every location along the long optical fiber, the light

propagating backward (away from the antenna) is polarized orthogonally to the light propagating forward (toward the antenna). The backward-propagating beam is separated in PBS1 and is coupled via an optical circulator to a photodetector. The photodetector is connected to a bias T, which separates the RF, LO, and intermediate-frequency (IF) components of the photocurrent. One of these frequency components is selected and is used as a feedback control signal to lock the frequency of the pump laser to a desired modulation sideband of the signal laser, as described in the paragraph after next.

A pump laser generates a beam of light needed for BSSA. The pump beam is coupled, via the optical circulator, into port 3 of PBS1. The polarization of the pump beam is so adjusted that the pump beam leaves PBS1 through its port 2 and propagates forward along the long optical fiber. After passing through the PBS2/modulator ring, the pump beam propagates back along the long optical fiber and enters port 2 of PBS1. Because of the action of the PBS2/modulator ring, the polarization state of the backward-going pump beam is orthogonal to that of the forward-going pump beam everywhere along the fiber. The polarization state of the forward-going pump beam is also everywhere the same as that of the backward-going modulated signal beam; this condition is optimum for Brillouin amplification everywhere along the fiber and eliminates the sensitivity of the Brillouin amplification to polarization. The pump beam leaves through port 1 of PBS1 and is attenuated by the optical isolator.

By tuning the frequency of the pump laser, one can make the narrow frequency-shift (Stokes-frequency) band associated with the Brillouin backscattering of the pump laser light to overlap one of the phase-modulation sidebands of the signal beam, thereby enabling Brillouin amplification of that sideband. The amplification of this modulation sideband breaks the perfect amplitude balance of sidebands of phase modulation and thereby converts the phase modulation to amplitude modulation. One can amplify either an LO or an RF sideband to obtain amplified IF and RF signals at the receiver. When the LO sideband is chosen, the beats of the amplified LO sideband with the upper and lower RF sidebands in the photodetector produce a down-converted and an up-converted IF signal, while the beat between the amplified LO sideband and the signal carrier produces an amplified LO signal.

This work was done by X. Steve Yao of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

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Electrodeposition of Strong Glassy Metals

Stresses in deposits can be tailored via compositions, temperatures, and current densities.

Marshall Space Flight Center, Alabama

Thin-walled structures made of strong glassy nickel and glassy nickel-cobalt alloys, with tailorable low residual stresses, and with high resistance to permanent plastic deformation, can be formed by use of an electrodeposition process. This process was developed to enable the fabrication of lightweight, high-quality x-ray mirrors that do not undergo unacceptably large distortions when differential thermal contraction upon cooling is used to release the mirror deposits from their electrodeposition mandrels. This process supplants an older pure-nickel electrodeposition process where it was necessary to form relatively thick deposits in order to make them strong enough to resist distortion in the presence of stresses imparted during release.

The process is based on the concept of selecting the composition of a plating bath and controlling the electric-current density to tailor the alloy composition and the level of stress in the electrodeposit. The plating bath contains a mixture of nickel salts, or nickel and cobalt salts with sodium hypophosphite. The bath also contains a surfactant and at least one complexing salt capable of combining with nickel, cobalt, and sodium. The pH of the bath is moderate; consequently, there is little risk of corrosion.

At low temperatures, cobalt contributes to compressive stress, while nickel contributes to tensile stress in the deposit. Thus, by suitable balancing of the ingredients in conjunction with the temperature and current density, it is possible to obtain zero net stress in the deposit throughout any desired thickness. Moreover, for a given suitable formulation of ingredients, the stress can be varied from compressive to tensile by varying the current density at a fixed temperature or by varying the temperature at a fixed current density.

The temperatures used in this process lie in the range from 35 °C, for glassy nickel-cobalt alloys, to 70 °C for glassy nickel; as a result, this process is safer than is an electroless process, widely used in airline repair centers, that involves temperatures from 85 to 90 °C. In this process, unlike in the electroless process, nickel, and cobalt when used, can be replenished by dissolution from anodes rather than by addition of chemicals. Little effort is required to maintain the plating bath in this process because any occasional chemical adjustments that must be made are much less critical than those needed in the electroless process.

A deposit formed in this process exhibits little or no plastic deformation at the parts-per-million level (microyielding) at stresses below 100 kpsi (0.7 GPa) and has an ultimate strength of greater than 200 kpsi (1.4 GPa). The deposit is also very hard (>50 Rockwell C), permitting diamond tool machining.

This work was done by Brian D. Ramsey of **Marshall Space Flight Center** *and Darell E. Engelhaupt of the University of Alabama in Huntsville. For further information, please contact Darell E. Engelhaupt at (256) 890-6030 or engelhd@email.uah.edu or Sammy Nabors, MSFC Commercialization Assistance Lead, at (256) 544-5226 or sammy.nabors@msfc.nasa.gov.*

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New Products

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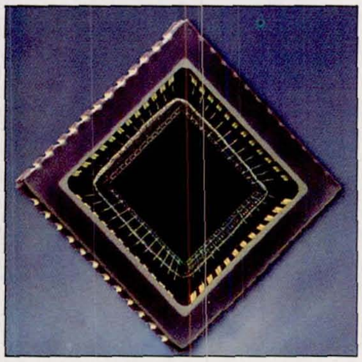
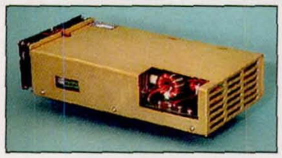
Product of the Month



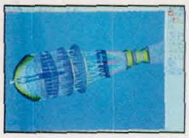
CMOS Image Sensor

Eastman Kodak's Image Sensor Division, Rochester, NY, describes its new KAC-0310 as a fully integrated, high-performance CMOS VGA image sensor, the first to be based on CMOS technology. The sensor, in a 1/3-in. format pixel array, has 640-x-480 active elements. The 7.8-μm-square pixels use Kodak's patented pinned photodiode architecture, which the company says provides significantly higher ISO speed capability compared to other CMOS devices. The sensors feature on-chip timing, programming control, analog signal processing, and a 10-bit analog-to-digital converter. The on-chip processing pipeline includes CDS, a frame rate clamp (FRC), and DPGAs for real time color gain correction. The devices are available in monochrome and color, with or without microlenses. They are housed in a 48-pin ceramic LCC package.



Laser Diode Power Module

The Model 5706 OEM laser diode power module from Analog Modules Inc., Longwood, FL, is designed to power high-current CW or QCW laser diodes and arrays for direct-coupled and diode-pumped solid-state laser applications. The Model 5706 delivers 500 W maximum output power, and can be configured for output currents up to 100 A CW with a 5-V load voltage or up to 50 A CW with a 10-V load voltage. The AC input is autoranging from 85-253 V AC. A DB-25 interface connector allows for external control of functions such as Inhibit, Current Control and Monitor, Load Voltage Monitor, and others.

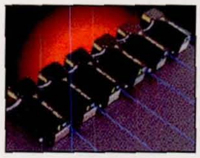


Illumination Design Software

Optical Research Associates (ORA), Pasadena, CA, announces LightTools® Version 3.0, the company's illumination design and analysis software for the PC. LightTools now utilizes the OpenGL® rendering engine, which ORA says delivers more realistic 3D rendering capability and an increase in display speed. Hardware acceleration is also provided by OpenGL-compliant graphics adapters. To improve scattered-light modeling capabilities, LightTools can now import measured bidirectional scatter distribution function data for a surface. This data can be used to model rotationally symmetric scatter, or fit to an elliptical Gaussian function to model anisotropic scatter.

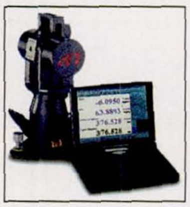
Gamma-Ray Radiation Detectors

eV Products, Saxonburg, PA, is offering coplanar grid (CPG) detectors, a line of CdZnTe-based room-temperature-operating gamma-ray detectors for nuclear spectroscopy. The CPG detector combines a large-volume CdZnTe detector and associated electronics in a portable design. The company says this detector has the required electrode geometry and charge collection efficiency to offer the high resolution necessary for nuclear spectroscopy. Shown is the CPG and electronics housed in a 31.75-mm diameter by 130-mm length probe.



High-Power DPSS Microlasers

Melles Griot, Carlsbad, CA, makes a new family of continuous-wave diode-pumped solid-state microlasers available. Dubbed the 58 BLD series, the new lasers come in configurations of 100, 200, and 400 mW at 457 nm. The output is linearly polarized. The air-cooled laser heads are less than 10 in. long, including cooling fan and heat sink, and total power dissipation is 100 W. M^2 factor for beam quality is less than 1.2, amplitude noise is less than 3 percent, and pointing stability is as low as 7 mrad/hr. The wavelength of the 58 BLD series is virtually identical to the 457.9 line of argon-ion lasers, making them an alternative to the latter for deep-blue and violet applications.

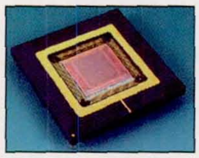


Laser Tracking System

The Laser Tracker II™ from Automated Precision Inc. (API), Gaithersburg, MD, provides linear and two-angle measurements relative to a reference point, making it particularly useful, the company says, for large-scale measurements, alignment, real-time assembly, tooling, remote dimensioning, fabrication, and reverse engineering. Standing 17 in. in height and weighing 27 lb., the package includes a frequency-stabilized laser interferometer and tracking unit, a retroreflector, sensors, cables, and software. A laptop computer is optional. The device can measure at a distance of more than 25 m; angle resolution is 0.3 arcsecond and distance resolution 1 micrometer.

Carbon Dioxide Laser Turning Mirrors

Laser Research Optics, Providence, RI, offers a line of carbon dioxide laser turning mirrors made from silicon with a variety of polarization-controlled reflectance coatings. The mirrors are fabricated in 1/2-in. to 3-in. diameter sizes with +0.000-in./-0.005-in. tolerances and thicknesses from 2 mm to 10 mm. Featuring less than 2 percent absorption and scatter losses, the mirrors are optimized for 10.6-micrometer @45 degrees AOI. Silicon and copper phase-retardation reflectors featuring a quarter-wave phase-reflectance thin-film coating are also offered, along with a line of molybdenum mirrors.



CMOS Sensor with Freeze-Frame Shutter

Photobit Corp., Pasadena, CA, introduces what it says is the first megapixel CMOS image sensor featuring a freeze-frame electronic shutter. The PB-MV13 has a 1.3 megapixel resolution and frame rate of more than 500 per second. Features include an output of 10-bit monochrome or color digital video with a pixel format of 1280 horizontal by 1024 vertical. Power consumption is less than 150 mW at 60 fps and less than 500 mW at 500 fps. The PB-MV13 incorporates Photobit's proprietary TrueSNAP™ (Shuttered Node Active Pixel) technology that features a 12-micron-square active pixel. Digital responsivity is 1000 bits per lux-second.

CMOS Block Microcamera

EMCO InterTest, Flanders, NJ, releases a new series of microcameras. Called EyeOn™, these cameras use a 1/3-in. CMOS array to gather and process video on-board, bypassing the external processing circuits required by CCD-based microcameras. Each EyeOn accepts +5.4 to +15.0 VDC, consumes 20 mA at +6 VDC, and outputs NTSC or PAL composite video. The chip inside each camera automatically corrects for white balance, brightness, and exposure. The sensor's image area measures 510 × 492 pixels (H and V), delivering a horizontal resolution of 330 TV lines with 2:1 interlacing. Exposure speed varies automatically from 1/60 to 1/15,734.

CCD Laser Measurement System

The LK Series CCD laser displacement meter from Keyence Corp., Oakland, NJ, is a semiconductor laser-based triangulation measurement system with 1.0-micron resolution and a ± 1 percent F.S. linearity. Keyence says it is available in a high-accuracy Model LK-031 (30 mm ± 5 mm range) and a long-range Model LK-081 (80 mm ± 15 mm range). These devices use a high-resolution CCD sensing array, which detects the peak value of the light quantity distribution of the beam spot for each pixel within the area of its 30-micron-diameter beam spot. Keyence says its accuracy is increased by Laser Flash Time Control technology, which automatically controls laser emission time to compensate for variations in target reflectivity and surface conditions.

Temperature-Compensated Resistors

Dallas Semiconductor, Dallas, TX, offers what it calls the first digital resistors that can automatically measure and compensate for thermal variations affecting laser behavior in optical transceivers. The company says the DS 1847 and DS 1848 provide precision temperature-compensated resistance control in gigabit Ethernet, fiber channel, SDH and SONET applications. The designer determines device-specific resistance characteristics at temperature intervals of 2 degrees C and stores the data in on-chip EEPROM. Both chips operate with either 3 V or 5 V supplies and within a temperature range of -40 degrees C to +95 degrees C.

Vol. 24, No. 11 November 2000 This form expires: April 2001

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Application Briefs

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Workers apply the clear laminating adhesive to a film adhered to the Space Station's innermost windows.

Eyesaver International of Hanover, MA, is working with NASA to laminate 16 to 18 windows measuring between 21" and 29" in diameter and 1/2" thick to be placed in the International Space Station's Laboratory Module and Cupola. The Laboratory Module will house experiments performed in near-zero gravity. With seven windows, the Cupola will offer the crew direct viewing of robotic operations, spacewalks, and experiments.

Eyesaver applies the 3M clear laminating adhesive to a non-hardcoated clear film adhered to the innermost window, referred to as the "scratch pane." The scratch pane is used to protect the outer window, and the film is attached to prevent glass from shattering inside the station. Eyesaver laminates the film and sends it to another company that polishes the film. A conductive bar is then soldered to the coating around the windows to keep the glass warm.

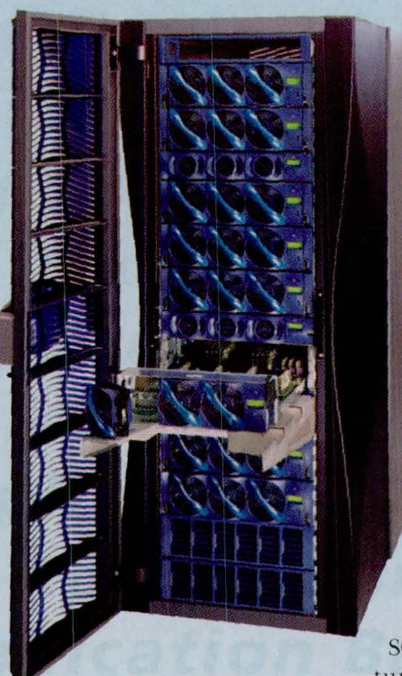
Steve George, co-owner of Eyesaver, explained that the film "has the optical clarity required by Boeing for photographing through the windows" of the Space Station. "Its uniformity is excellent, there is zero distortion, no coating voids, and the flatness has been unmatched."

The adhesive is manufactured under cleanroom conditions and is free of common adhesive defects such as bubbles and dirt. It provides greater than 99% light transmission, and a haze level of less than 0.1% for transparency. The Space Station windows are expected to be ready for installation this fall.

For More Information Circle No. 750

NASA Ames Begins Building Supercomputer

SGI™ Origin 3000 Series computers
SGI Federal
Mountain View, CA
301-572-1980
www.sgi.com



NASA Ames Research Center in Moffett Field, CA, is developing a 1,024-processor supercomputer using two 512-processor SGI Origin 3800 systems based on the NUMAflex™ modular technology. NASA will use the system for research in the areas of aeronautics, earth sciences, and life sciences.

NASA Ames currently uses a 512-processor SGI 2800 Lomax system for computational fluid dynamics, global climate modeling, and computational astrobiology. The new system is expected to "deliver about six times the performance at 1,024 processors as the 512-processor system," said Bill Feiereisen, chief of the Numerical Aerospace Simulation Systems Division at Ames. The system allows NASA to configure and reconfigure systems brick by brick to meet exact demands for their applications.

According to Feiereisen, floor space at Ames is at a premium, so the reduced footprint of the new systems is an advantage. If it had been twice the size of the old one, "then we wouldn't have had room for it," he said. Since the new system has twice the number of processors per square foot, Feiereisen can "push machinery around to make room for it."

The Origin 3000 system is based on SGI's NUMA architecture and IRIX® 6.5 operating system, and works with NASA Ames' existing application software, including its Overflow-MLP computational fluid dynamics code. According to SGI, the NASA Ames system features the largest single-kernel, shared-memory image available today.

For More Information Circle No. 751

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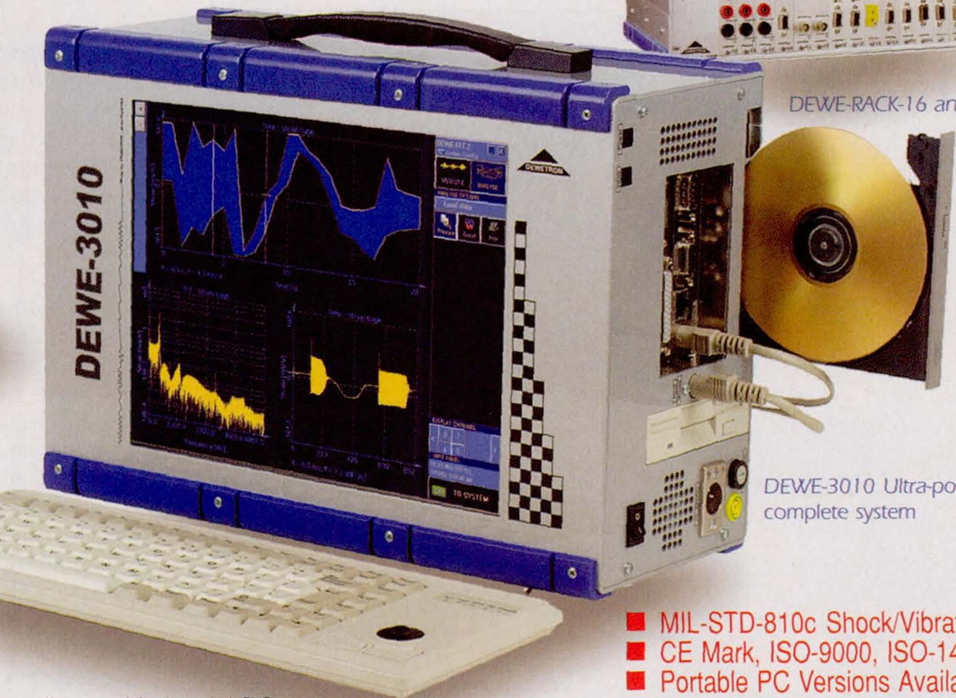

DEWE-3010 Ultra-portable complete system

Commercialization Opportunities

Helium Leak Detector With Improved Sample-Delivery System

Developed to detect fuel leaks in space shuttle main engines by use of helium tracer gas, this system may locate leaks safely in other systems carrying toxic or explosive fluids.
(See page 46.)

Gas Analyzer Measures Concentration of H_2, O_2, and H_2O

By monitoring He used to purge hydrogen carrying tubes, this apparatus helps to ensure that the system no longer contains dangerous hydrogen.
(See page 49.)

Improved Coatings for Flexible Insulating Blankets

Improved coatings increase the ability of flexible thermal-insulation blankets to resist erosion. Developed for space shuttle orbiters, these materials could also be applied to terrestrial insulating blankets on aircraft, engine, and furnace components.
(See page 54.)

PBO Fiber Blends: A Promise for the Future

New developments in fiber blends for space suits and micrometeoroid shields could lead to improved body armor, firefighters' suits, and tethers for parachutes or aircraft.
(See page 54.)

Air-Displacement Volumometer With Soft Sides

Complete submersion of the subject in water is no longer necessary to measure the volume of a human body. This unit may be used in hospitals, medical research facilities, clinics, and athletic facilities and to measure volumes of other objects with dimensions comparable to those of a human body.
(See page 58.)

Technique for Controlling Gas Generation in a Bioreactor

A pressure-swing technique controls the generation and flow of gas in an anaerobic biological reactor and associated equipment in a system that processes wastewater. Prevention of gas bubbles maintains the efficiency of the wastewater treatment.
(See page 63.)

Liquid Shell Insulation

This type of insulation would offer temporary thermal protection for scientific instrument probes operating in hot, high-pressure environments.
(See page 71.)

Fluorometer for Analysis of Photosynthesis in Phytoplankton

A new design promises to be a relatively inexpensive, sensitive, compact, rugged, low-power-consumption instrument for studying phytoplankton. It can also be adapted to agricultural applications.
(See page 79.)

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For More Information Circle No. 522

The Role of the Internet in Design and Analysis

Engineers are increasingly using the Internet to communicate about their engineering projects during the design and analysis process. As a result, the Internet must play an important role in both training and the dissemination of information.

The Internet is becoming a part of the fundamental design and analysis process. What started as a mechanism for communication and data sharing has evolved into an enterprise solution for design management, analysis, and education. The future is even more exciting, promising collaborative engineering and immersive virtual reality. While it may be decades before mainstream engineers are working in such an environment, we already are seeing design and analysis software companies supporting engineers in new and revolutionary ways.

By now, the genesis of the Internet is well known. The Internet began in 1969 as ARPANET, a research project studying failsafe network communication sponsored by the Department of Defense. Early usage of the Internet for engineering purposes was limited to communication via e-mail and bulletin boards, and file transfer via FTP. The introduction of the Mosaic browser in 1993 revolutionized how the Internet was used by providing a visual interface for searching and retrieving HTML web pages, which was infinitely more intuitive than earlier tools.

Today, an ever-growing number of Internet technologies drives dynamic, multimedia sites. FEA (finite element analysis) companies support engineers with e-commerce, user groups, e-mail newsletters, and online technical support. As higher bandwidth connections become more widely available, the transmission of highly graphical video content is causing a revolution in software education for engineers.

The Internet as an Educational Tool

Changes within the engineering industry have increased the demand for quality software training that is inexpensive, time-efficient, and accessible from anywhere. In the past, design and analysis were performed by separate groups within an engineering firm. Design engineers sat at drawing boards and based their prototype designs on handbook calculations. The designs were validated with detailed stress analysis using FEA by analysts who possessed specialized training and analytical experience. The distinction between design engineers and analysts has become more blurred as designers have access to complete analytical capabilities within an integrated CAD/CAE environment, and as interfaces for analysis become more intuitive and easier to use. The capability to right-click on a solid model and apply, modify, and remove loads, constraints and finite element properties for a wide variety of analysis types within a CAD environment has helped to make FEA more accessible to all engineers, even those who are not FEA experts.

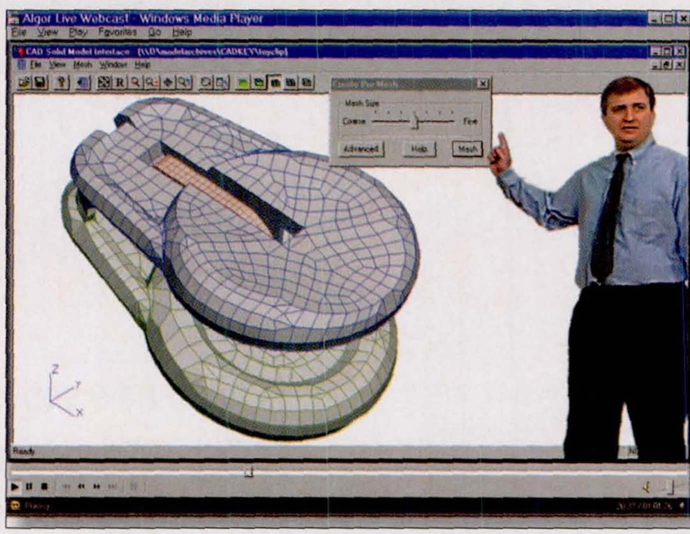


Photo 1: Webcasting uses the Internet to fill the demand for quality engineering software education with full-screen, TV-quality video. The technology enables engineers to perform a variety of FEA analysis in an integrated environment within the CAD package.

Because more designers are performing analysis without necessarily possessing the training that analysis specialists have, one of the most important roles the Internet must play in the design/analysis process is as a vehicle for training and for the dissemination of information about FEA. Streaming video, often referred to as "webcasting," has emerged as the leading technology for distance learning because of its capacity to deliver detailed, full-screen graphics.

At the highest level, TV-quality, full-screen video simulates a true virtual classroom by showing the details of the instructor's computer on the student's computer. This high level of production quality is complemented by a high level of presentation quality with point-and-click details presented by knowledgeable instructors to step engineers through the FEA process. This level of technology also might be available on CD-ROM or VHS videotape, so engineers can benefit from this technology regardless of their Internet connection speed.

Communicating Designs on the Internet

Once an engineer has learned how to use FEA software and performed an accurate analysis, the results of the analysis often must be communicated to colleagues and clients who may be located

across oceans and continents in today's global marketplace. Engineers are increasingly using the Internet to communicate about their engineering projects during the design/analysis process. They are being supported by a host of easy-to-use HTML generation tools. While many such tools are available within office productivity software packages, FEA software ideally includes a wizard-type tool to automatically collect details about a FEA model and its analysis results, and generate an organized report in standard HTML, which can be published to any Internet or Intranet site. HTML report wizards may include sections for customized, user-specified information. One exciting technology for communicating about designs within an HTML report is the VRML (Virtual Reality Modeling Language) file format, which is supported by many CAD/CAE software packages. A VRML file enables 3D viewing of solid geometry with dynamic zoom, pan, and rotation capabilities.

Possibly the most interesting direction that CAE software is taking is the move towards collaborative design engineering, where engineers can share data in "design webs" over the Internet. While original CAD software was limited to geometry modeling, today's software stores more complete information about the product, including materials and manufacturing data. Integrated CAD/CAE tools are able to utilize this additional information to allow the designer to perform a wide variety of FEA analysis types from within the CAD package, including simulation of motion, deformation, and stresses in a virtual design environment. In addition, FEA data may be stored in a database format to facilitate multiphysics analyses, which consider multiple physical phenomena. FEA model databases also enable the integration of FEA data with other database sources, such as laboratory data, and other types of software applications. While most engineers are not yet working in an immersive virtual reality environment, the day clearly is not far off.

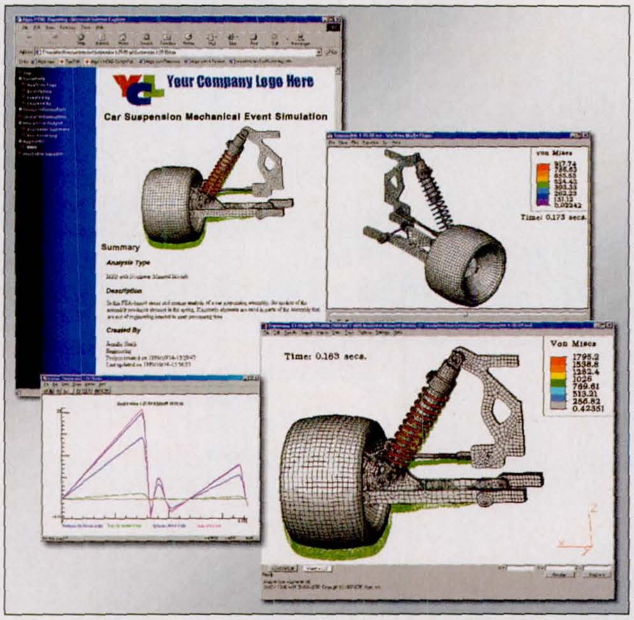


Photo 2: Algor's automatic HTML Report Wizard enables engineers to communicate analysis results to colleagues over the Internet. In HTML reports like this one (upper left), different types of visual output can be incorporated, including a stress contour at one moment in time (lower right), the time-dependent results as recorded in an animation file (upper right), and a plot of the displacement of several parts of the model over time (lower left).

For more information, contact the author of this article, Ed Moas, Ph.D., software developer, at Algor, Inc., Pittsburgh, PA; Tel: 412-967-2700; or visit www.algor.com.

Special Coverage: Design & Analysis Software

Program Predicts Jet Noise

John H. Glenn Research Center, Cleveland, Ohio

MGBK is a computer program that predicts the mixing noise and the shock noise generated by a subsonic or low-supersonic jet, given input data on the mean flow and turbulence fields as predicted by a suitable state-of-the-art computational fluid dynamics (CFD) program. More specifically, MGBK can be regarded as a post-processing program for use with a CFD program that computes a Reynolds-averaged Navier-Stokes solution with turbulence represented by a mathematical model of a type known in the art as "$k - \varepsilon$" [in which k denotes the time-averaged kinetic-energy density associated with the local fluctuating (turbulent) component of flow, while ε denotes the time-averaged rate of dissipation of this turbulent-kinetic-energy density]. The predictions generated by MGBK are in the forms of sound-pressure levels and frequency spectra on arcs or sidelines.

MGBK is an updated version of a noise-prediction program, called "MGB," developed during the 1970s. MGBK predicts only the noise generated in the part of a jet plume external to the exit plane of the nozzle of a jet engine; it does not predict mixing or turbomachinery noise generated within the engine. Still, in cases in which external mixing is the dominant cause of noise, MGBK could prove valuable for understanding noise and reducing noise through improvements in the designs of nozzles and/or mixers.

The approach taken in the development of MGB and MGBK has been one of mathematical modeling of noise sources associated with turbulence. In order to predict noise by use of MGBK, one must use an H-type structured computational grid with slices perpendicular to the direction of mean flow. The input to MGBK comprises data on the CFD-predicted flow field on this grid, plus several parameters. Although the prediction of noise applies to the external part of the jet plume only, boundary conditions in CFD predictions are specified well upstream of the nozzle exit and from 20 to 30 diameters downstream of the exit plane.

The input data are processed by means of semiempirical mathematical models of noise-source strength and acoustic propagation. The source model includes both self and shear noise-source terms. Anisotropy of turbulence is incorporated into the source model via an axisymmetric turbulence submodel. Inasmuch as noise is a byproduct of turbulence, the noise predictions of MGBK are unavoidably sensitive to the details of both the CFD input and the noise models and, hence, some degree of empiricism unavoidably enters via the models.

This program was written by Abbas Khavaran of Dynacs Engineering Co. for **Glenn Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17062.

Program for Analyzing Static Transmission Error of Helical Gears

John H. Glenn Research Center, Cleveland, Ohio

The computer program HeliStat performs finite-element analysis to simulate meshing of helical gears. This program is a logical extension of the program DANST, which applies to spur gears. [DANST was described in "Computing Stresses in Spur Gears (LEW-15420), *NASA Tech Briefs*, Vol. 19, No. 12 (December 1995), page 73 and "Updated Program for Computing Stresses in Spur Gears (LEW-16575) *NASA Tech Briefs*, Vol. 22, No. 8 (August 1998), page 59.]

HeliStat performs a geometric tooth-contact analysis to determine the lines of tooth contact, and then it performs a three-dimensional linear static analysis to determine tooth-meshing stiffness, tooth deflections under static load, and the static transmission error. The results of the static analysis are available to the user in the form of static transmission error as a function of rotation as well as the peak-to-peak transmission error. Since the transmission error is the major source of dynamic excitation that causes gear vibration and noise, HeliStat can help a gear designer develop quiet gears.

The mathematical model upon which HeliStat is based includes representations of the driving and driven gears, connecting shafts, and supporting bearings. The model also includes provisions for gear-tooth modifications either perpendicular to the lines of contact (cross-modification) or in the profile and longitudinal directions. HeliStat can be used for parametric studies of the effects on the transmission error of helical-gear systems due to torque, tooth stiffness, and gear-tooth modifications.

This program was written by H. H. Lin of the University of Memphis and Fred B. Oswald of **Glenn Research Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16877.

Software for Multidisciplinary Analysis of Optical Systems

NASA's Jet Propulsion Laboratory, Pasadena, California

Integrated Modeling of Optical Systems (IMOS) is a MATLAB™ computer program that provides many functions for analysis of a system represented by mathematical models of its thermal, structural, control, and/or optical aspects. For example, IMOS can be used to study thermal distortion of structural components of an optical instrument and the resulting degradation of optical performance. Heretofore, such an analysis would have entailed the use of separate programs to perform thermal, structural, control, and optical sub-analyses. The uniqueness of IMOS lies in the possibility of performing the entire analysis in one program. The common MATLAB™ software environment offers several advantages, including capabilities for optimizing the design of a system on the basis of multidisciplinary (e.g., thermal and optical) criteria and a capability for optimizing the designing of the control subsystem. IMOS provides interfaces between itself and several other programs, including NASTRAN to IMOS, IMOS to SINDA, IMOS to TSS, and IMOS to MACOS. Both MATLAB and IMOS have plotting capabilities that assist in visualization of results.

This program was written by Laura Needels, Hugh Briggs, Andrew Kissil, Daniel Eldred, Marie Levine, James Melody, Mark Milman, Robert Norton, Samuel Sirlin, Miltiadis Papalexandris, Terry Scharton, and Wan Tsoi of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20536.

Software for Multidisciplinary Analysis of Graded Composites

John H. Glenn Research Center, Cleveland, Ohio

The Coupled Structural/Thermal/Electromagnetic (CSTEM) computer program implements an integrated multidisciplinary approach to analysis and optimization of the designs of graded composite-material structures. The name of the program reflects recognition of the coupling among thermal, electromagnetic, mechanical, and other phenomena in such structures. The integrated multidisciplinary approach is necessary because the coupling among the phenomena gives rise to complexity and contributes to nonlinearity in the characteristics and responses of the structures, such that separate analyses of a structure according

to traditionally separate disciplines (e.g., acoustics, structural vibrations, structural loads, thermal effects, and electromagnetic properties taken by themselves) could lead to erroneous conclusions.

CSTEM is written in FORTRAN and is an extended and updated version of the program described in "Multidisciplinary Design of Hot Composite Structures" (LEW-15977), *NASA Tech Briefs*, Vol. 20, No. 3 (March 1996), page 24. As in that program, an essential feature of the multidisciplinary approach is finite-element numerical simulation of the relevant physical phenomena according to the applicable disciplines. The code includes (1) analysis modules that perform calculations pertaining to the separate disciplines and (2) an executive subprogram that controls an iterative solution procedure in which coupling and nonlinearity are taken into account by means of communication of input results among, and coordination of the functions of, the analysis modules. Each analysis module receives the relevant input geometric and control data and transmits any results that may be needed as input for another analysis module.

A notable advanced feature of CSTEM is a capability for analysis of a heterogeneous composite-material structure that contains multiple material layers or other regions, without the necessity of using one element for each layer or region. Such properties as the stiffness, thermal conductivity, and electromagnetic absorptivity of an element that comprises multiple layers or other regions are calculated by use of integration points located at the centroids of the layers or other regions within the element. The composite gradients control the finite-element definition of a structure, with two parameters that can be varied: the number of elements along the gradient and the number of numerical quadrature points within an element.

The structural-analysis module performs a large-deformation analysis, using a unique incrementally updated Lagrangian with iterative refinement. Associated with the large-deformation structural-analysis module is a deformed-position vibration-mode-analysis module. The thermal- and electromagnetic-analysis modules use the same finite elements as does the structural-analysis module; this feature facilitates coupling among the modules.

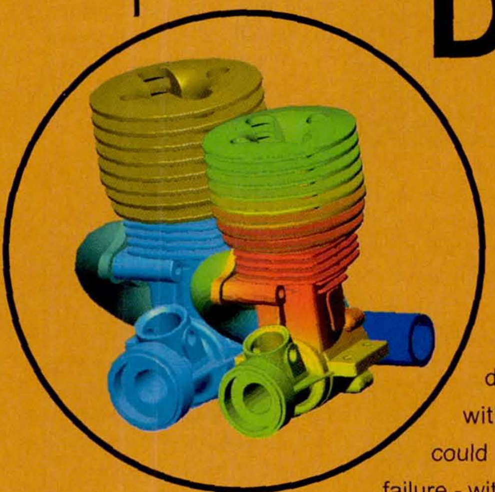
Some other notable features of CSTEM include the following:

- Capabilities for nonlinear-buckling, transient-heat-transfer, internal-damage (creep, plasticity, fatigue), and acoustical analyses;
- Computation of macroscopic properties of a composite material from the properties of the constituent materials at the microscopic level;
- Computation of electromagnetic absorption of a composite material by use of an easily modifiable database of absorption properties of constituent materials; and
- A capability for generation of internal computational meshes.

This program was written by Christos C. Chamis, Charles A. Farrell, and Bruce N. Canright of **Glenn Research Center** *and Richard L. McKnight, Michael S. Hartle, and Hsin-Tien Huang of General Electric Co. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17052.

Don't Take Chances with your Designs



Will it overheat? Will the stresses be too high? Will it break? If you are designing your models without using analysis, you could be risking a potential part failure - without even realizing it. Don't take unnecessary chances with your design. Use COSMOS/ throughout the design cycle to help identify potential problems before it's too late.

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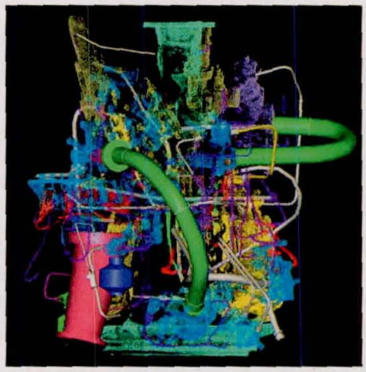
For More Information Circle No. 508

Special Coverage: Design & Analysis Software

LAPCAD Engineering, San Diego, CA, offers LapFEA Release 5 **finite element analysis software** for Windows and PowerMac systems. The new release features an increased nodal capacity of 30,000, from the previous level of 5,000. This enables completion of more complex finite element modeling, analysis, and postprocessing.

The nodes — an entity by which finite elements are connected to each other — move along three axes and rotate around the same axis, having a maximum of six degrees of freedom. The software is priced based on the number of nodes. Versions are available with 1,000, 5,000, 10,000, or 20,000 nodes.

For More Information Circle No. 711



3Dipsos 2.4 **3D modeling software** is available from MENSI, Norcross, GA. The software features a new user interface, a visualization function for model visualization from point clouds prior to modeling, table-driven modeling, interactive copy commands, and beam and box extraction routines. It can be used to construct triangulated meshes directly from clouds of points.

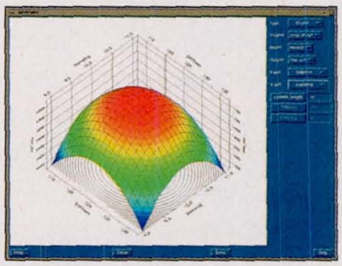
Point cloud data is processed into 3D models; the user can manipulate the model, extract its geometry, or create surface models and output them to various modeling, simulation, or CAD products. The software also features automatic image and texture mapping onto scanned surfaces, and automatic registration of multiple scanned points of view.

For More Information Circle No. 713

Altia, Colorado Springs, CO, offers Altia Design **graphical product simulation software** with a Java application program interface that connects programs written in Java to the graphics created in Altia Design. The software provides custom graphics for new product simulations and virtual prototypes. Users are able to post a working virtual prototype on a Web page and allow other team members to view it and interact with it.

The software also allows the creation of monitoring and control screens, enabling use of the Internet to remotely monitor instrumentation and control devices across multiple locations. Interactive, animated graphics can be created without programming. The software connects to most system simulation tools and programming languages.

For More Information Circle No. 716



LMS OPTIMUS 3.0 **CAD optimization software** from LMS North America, Troy, MI, works with major mechanical engineering software programs to enable the user to understand how changes affect their designs. It automatically identifies the design's sensitivity to a range of parameters. A new network display allows parameters to be grouped together to simplify the display for large sets of variables. Users also are able to schedule simulation tasks to run over a parallel network of workstations or PCs.

Ranges, values, names, and data sets can be validated before a Design of Experiments (DOE) is launched. The DOE optimization process allows users to view progress, interrupt, and interact with the analysis. The DOE module features methodologies such as full and fractional Factorials, Taguchi, and Placket Burman. New optimization methods include two types of evolution methods and a simulated annealing algorithm.

For More Information Circle No. 712

Ashlar, Austin, TX, has introduced Vellum Solids 2000 **3D modeling software** for Windows and Macintosh platforms. New features include modeling of complex shapes, and interoperability with new file translators for importing directly from Pro/ENGINEER, as well as ACIS STEP and IGES. Extended rendering tools provide material editing, shadow control, and improved filleting, blending, and chamfering.

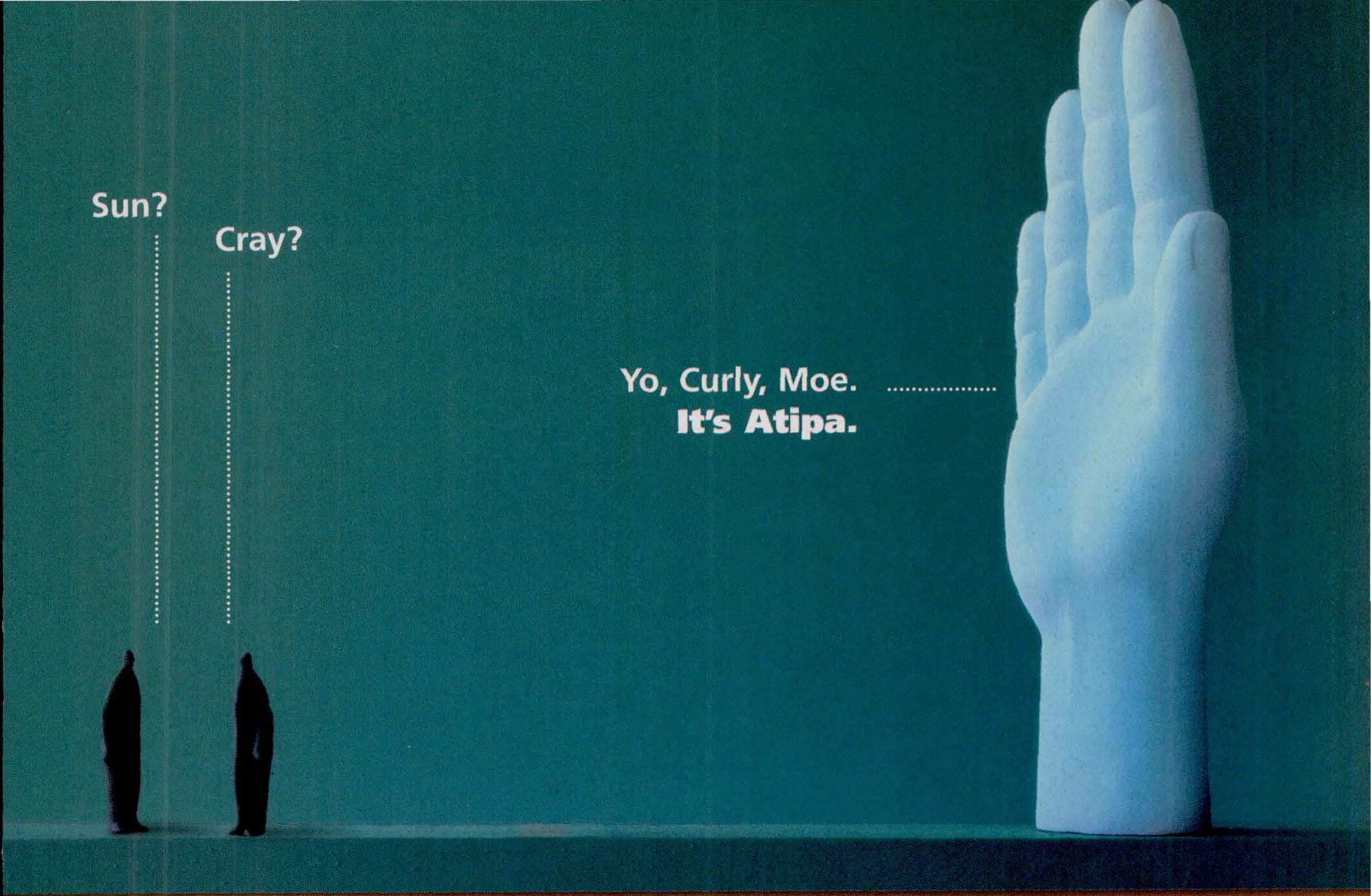
Surface creation and editing capabilities include continuous surface matching; elevation, control point manipulation, and insertion; an untrim function; and guide curves. New surface verification features include draft angle, curvature normals, and zebra plots.

For More Information Circle No. 714

Unigraphics Solutions, St. Louis, MO, has introduced Solid Edge Version 9 **mechanical design software** that features more than 300 enhancements for 3D CAD. New assembly modeling capabilities include a weldment design environment for modeling welded components in large machinery assemblies. DesignAssistant sensors provide monitoring of the design process using meter-like readouts to alert designers of any violations of user-defined parameters.

Solid Edge Web Publisher, an integrated module of the program, enables users to create web content from Solid Edge design data. The module creates web pages with compact 3D product models that can be viewed and manipulated with the Microsoft Internet Explorer browser. The Xpand3D module automatically creates solid models from 2D CAD drawings, enabling users to migrate from 2D to 3D modeling.

For More Information Circle No. 718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Cray?
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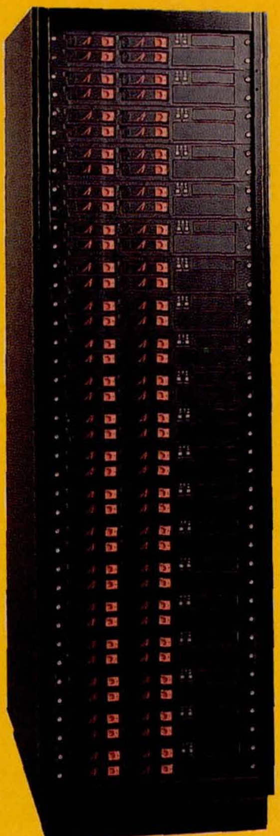


Electrically Isolating, Thermally Coupling Devices

Digital signals would be coupled thermally instead of electrically or optically.

NASA's Jet Propulsion Laboratory, Pasadena, California

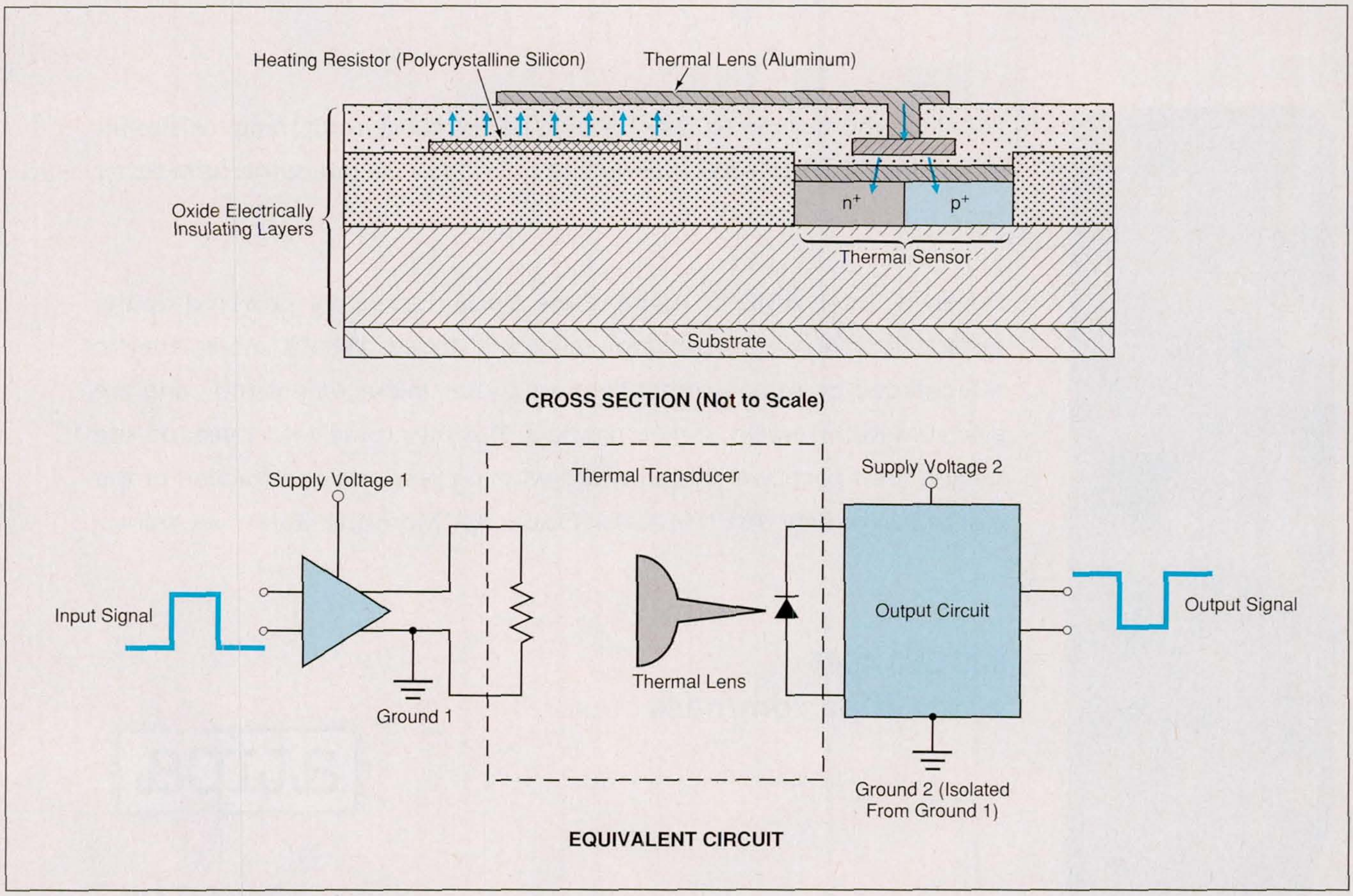
Integrated signaling devices of a proposed type would utilize thermal coupling to transfer digital signals between electronic circuits that are required to be kept electrically isolated from each other. The proposed devices would be implemented as silicon-on-insulator complementary metal oxide/semiconductor (SOI CMOS) integrated circuits and could therefore be readily integrated with other SOI CMOS devices. For some applications, the proposed devices could be an attractive alternative to conventional optocouplers, which have not been amenable to integration with CMOS devices because of a lack of silicon-based integrated sources of light.

The thermal-coupling concept offers a major advantage at the outset: There are several possible methods for on-chip conversion of electrical signals to thermal ones, and there already exists a significant body of published work on the conversion of thermal signals to electrical ones.

Though optimization of design can be expected to entail significant effort with attention to minute details, the basic principle of operation and design concept (see figure) is straightforward. The device would include an input circuit (e.g., an amplifier), through which an input digital signal pulse would be applied to a resistor to generate a pulse of heat. The thermal pulse would be conducted from the resistor, through an electrically insulating barrier, to a thermal sensor.

The resistive heater could be made of polycrystalline silicon. The thermally conducting, electrically insulating barrier would likely be made of a thin layer of SiO_2. A simple thermal lens could be made from a suitably patterned surface layer of aluminum. (A more complex thermal lens might also include micromachined, embedded metallic heat pipes to decrease the thermal-response time.) The thermal sensor could be a silicon p/n diode.

A possible disadvantage is that the characteristic times of thermal propagation of signals could limit the speed of such a device. The propagation delay, coupling efficiency, and degree of electrical isolation of the thermal-transducer portion of the device are related to a combination of several geometrical factors. For example, as the distance between the resistor and the thermal sen-



An Electrically Isolating, Thermally Coupling Device according to the proposal would be an SOI CMOS integrated circuit that would include an input electronic circuit, an electrically isolating thermal transducer, and an output electronic circuit.

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• AC volts	100nV – 750V	100nV – 750V	100nV – 775V	100nV – 775V
• Ohms	100µΩ – 120MΩ	1µΩ – 120MΩ	1µΩ – 1GΩ	100nΩ – 1GΩ
• DC amps	10nA – 3A	1nA – 3A	10pA – 2.1A	10pA – 2.1A
• AC amps	1µA – 3A	1µA – 3A	100pA – 2.1A	100pA – 2.1A

For More Information Circle No. 544

sor increases, the speed and the coupling efficiency decrease. The shape of the lens also exerts a significant effect on the coupling efficiency and speed.

Another major concern is that of input power. High instantaneous input power would translate to a larger signal and faster input/output coupling, but there is also a need to conserve energy and minimize spurious heating. A smarter alternative would be to design an input driver circuit that would produce (1) a shorter higher-power electrical pulse to generate a rapidly rising thermal pulse, followed by (2) a longer, lower-power pulse for maintaining the thermal pulse. The higher-power initial input pulse would thus ensure the rapid triggering of the output circuit via the thermal sensor, and the subsequent longer, lower-power input pulse would guarantee the triggered state of the output circuit. The combination of the two power pulses would result in less power demand than would the use of simple high-power pulses. It would be necessary to select an optimal combination of power levels and pulse durations as a compromise between minimizing average power consumption and maintaining the integrity of signals.

A third major concern is that the thermal signal would include a varying ambient-temperature component. It would be necessary to design the output circuit to reject this component and rapidly convert the rest into an equivalent electrical signal. Two key parameters for designing this circuit are the resolution of the thermal detector and its conversion speed. It may be necessary to amplify the output of the thermal sensor and feed the amplified signal as input to an output driver with digital hysteresis.

This work was done by Mohammad Mojarradi of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-20640, volume and number of this NASA Tech Briefs *issue, and the page number.*

Improved Ignitor and Keeper Power Supplies for Hall Thruster

The key to reliable operation of a cold cathode is correct power-supply waveforms.

John H. Glenn Research Center, Cleveland, Ohio

Ignitor and keeper power supplies have been developed specifically for a Hall-effect thruster with a cold cathode. Prior to the development of these power supplies, difficulties had been observed in the operation of cold-cathode Hall thrusters; in particular, they did not start reliably upon turn-on of power. Many specialists in Hall thrusters had attributed the difficulties to the characteristics of cold cathodes as distinguished from those of hot cathodes.

The development of the present ignitor and keeper power supplies was guided by the observation that the key to reliable operation of cold-cathode Hall thrusters is to use correct power-supply waveforms and that the unreliability of startup observed previously was caused by the use of incorrect waveforms. The present power supplies comprise (1) an ignitor supply that produces a clean 1,000-V pulse with no undershoot and (2) a current-limited keeper supply. The combination of these power supplies produces a waveform that can be relied upon to start operation of a cold cathode on a stationary plasma thruster. The waveform produced by these power supplies can also be used to clean a cathode that has been contaminated by exposure to the environment.

This work was done by See-pok Wong, E. "Ned" J. Britt, and Raymond Lin of Space Power, Inc., for **Glenn Research Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16490.

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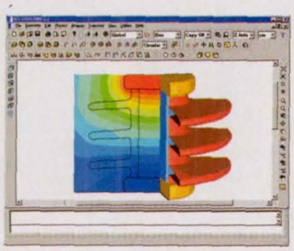

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Magnetic Technologies Corp, Rochester, NY.

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Assistant Engineering Manager, Industrial Coils, Baraboo, WI.

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Helium Leak Detector With Improved Sample-Delivery System

The pressure at the inlet of a mass spectrometer is regulated.

John F. Kennedy Space Center, Florida

The figure schematically depicts a portable helium leak detector that includes an improved sample-delivery system. This instrumentation is designed for detecting leaks in the fuel and oxidizer systems of the space shuttle main engines. In a helium leak test, helium is used as a tracer gas in place of the hazardous fuel or oxidizer: The fuel or oxidizer plumbing of interest is pressurized with helium. The aft section of the space shuttle (which section contains the plumbing) is purged with air, and the portable helium leak detector is used to monitor for any increase in helium content of the purge exhaust at concentrations down to the part-per-million level. The portable helium leak detector can also be used to perform tests to detect very small leaks in systems other than the space shuttle main engines.

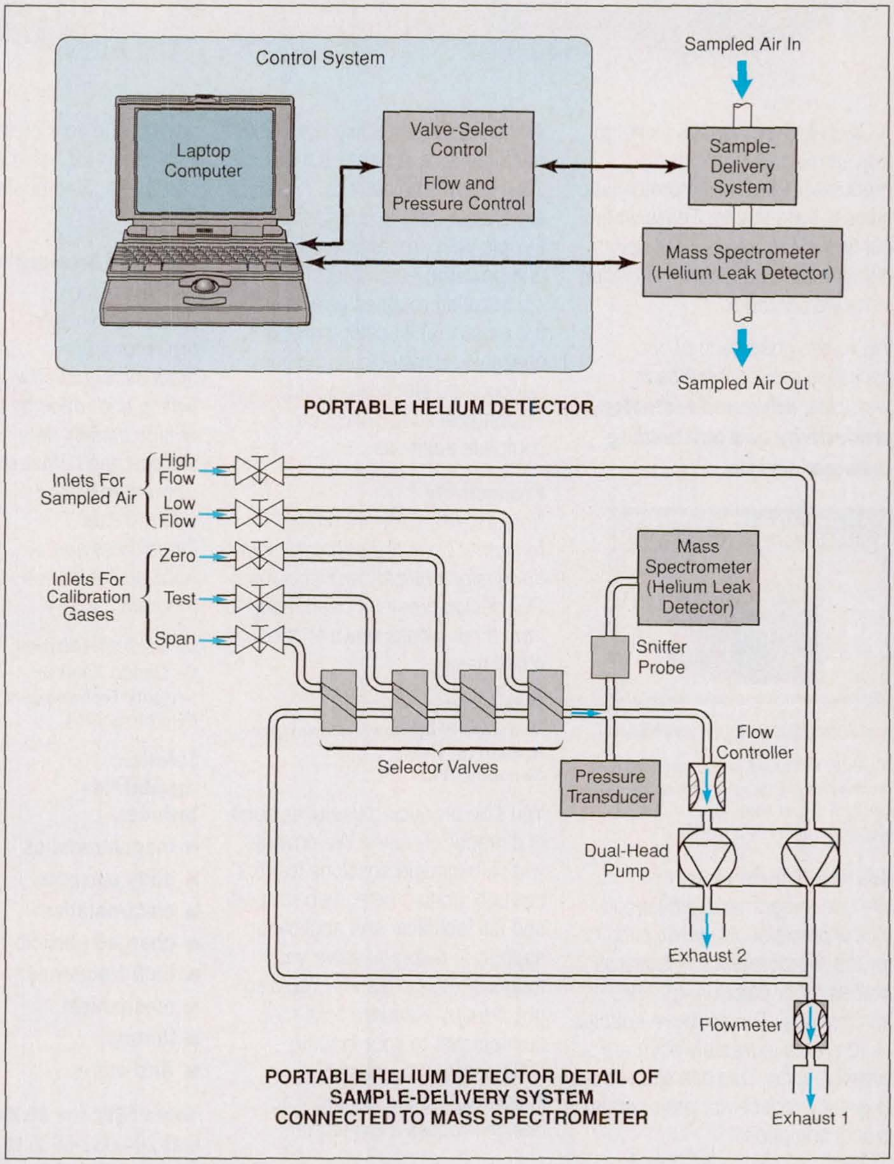
The portable helium leak detector includes three instrumentation modules: a commercial helium leak detector, a control system, and a sample-delivery system. These modules, plus gas supplies, are mounted on one cart that can be wheeled to the test location.

Like other commercial helium leak detectors, the present one is essentially a mass spectrometer designed specifically for detecting helium. The inlet of the mass spectrometer is attached to the outlet of the sample-delivery system. The mass spectrometer is connected to the control system via an RS-232 serial data port.

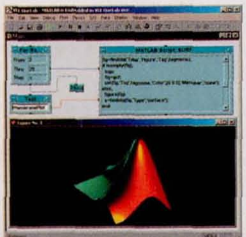
The control system includes a laptop computer connected via serial data ports to solid-state relays and analog-to-digital converters that, in turn, are connected to the mass spectrometer and the sample-delivery system. The computer runs LabVIEW software that controls the general sequencing of events, the switching of valves, and the acquisition of data. The computer sends the valve commands to solid-state relays that turn power on and off, as commanded, to control the valves. The output signals from a temperature sensor and from the mass spectrometer are sent to the computer via the analog-to-digital converters.

The software monitors and displays long-term (a test can take several hours) leak trend data and saves all pertinent information on the hard drive of the computer. The software provides options for performing self-calibration and self-leak tests. Control menus on the computer display are grouped as pages or screens that include a setup page, a self-leak-check page, an autocalibration page, and pages dedicated to specific test setups. New pages can readily be added as needed.

The sample-delivery system includes pumps, valves, pressure transducers, and mass-flow controllers, all working together to bring a sample from the atmosphere of interest to the inlet of the mass spectrometer. The sample-delivery system includes two inlets: one for high flow and one for low flow. The high-flow inlet is for use at high volumetric purge flow rates and enables the rapid detection of leaks. The low-flow inlet is for use in tests that involve little or no purge flow.



The **Portable Helium Leak Detector** is a cart-mounted system of three modules. One of the modules is the sample-delivery system, which delivers sampled air to the inlet of the mass spectrometer at regulated pressure.



For More Information Circle No. 584

The most novel aspect of the design of the sample-delivery system is a provision for regulating the pressure at the inlet of the mass spectrometer. The mass spectrometer effectively measures the partial pressure of helium and therefore it is desirable to regulate the total inlet pressure in order to ensure that the measured partial pressure bears a known proportionality to the concentration of helium in the sampled air. The regulation of the inlet pressure is effected by a feedback loop between a pressure transducer and a flow controller. Another unique aspect of the instrument is its ability to be calibrated and provide data as parts-per-million leakage rates. This is done to match the space-shuttle main-engine permissible leakage-rate criteria.

The entire portable leak detector (including the cart) is 23 in. (58 cm) wide, 45 in. (114 cm) high, and 30 in. (76 cm) deep, and has a weight of 346 lb (mass of 157 kg). The three modules can easily be removed to facilitate transport. All three modules are powered via a single 115 Vac outlet.

This work was done by Fredrick Adams, Carolyn Mizell, David Collins, and Gregg Breznik of **Kennedy Space Center**; *Richard Hritz, Francisco Lorenzo-Luaces, Guy Naylor, Curt Lampkin, Timothy Griffin, and Terry Greenfield of Dynacs Engineering Co., Inc.; and Larry Lingvay formerly of I-NET, Inc. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Test and Measurement category. KSC-12054*

Fiber-Optic Sensors for Measuring Oxygen Dissolved in Water

Colors of immobilized metal complexes change in the presence of dissolved oxygen.

John F. Kennedy Space Center, Florida

Fiber-optic sensors for measuring concentrations of oxygen dissolved in water are undergoing development. In comparison with electrochemical dissolved-oxygen sensors, the fiber-optic sensors are expected to be easier to use and maintain. Also, unlike electrochemical dissolved-oxygen sensors, the fiber-optic dissolved-oxygen sensors are amendable to connection into networks for taking measurements at multiple sites.

The fiber-optic sensors detect oxygen through changes in color. A sensor of

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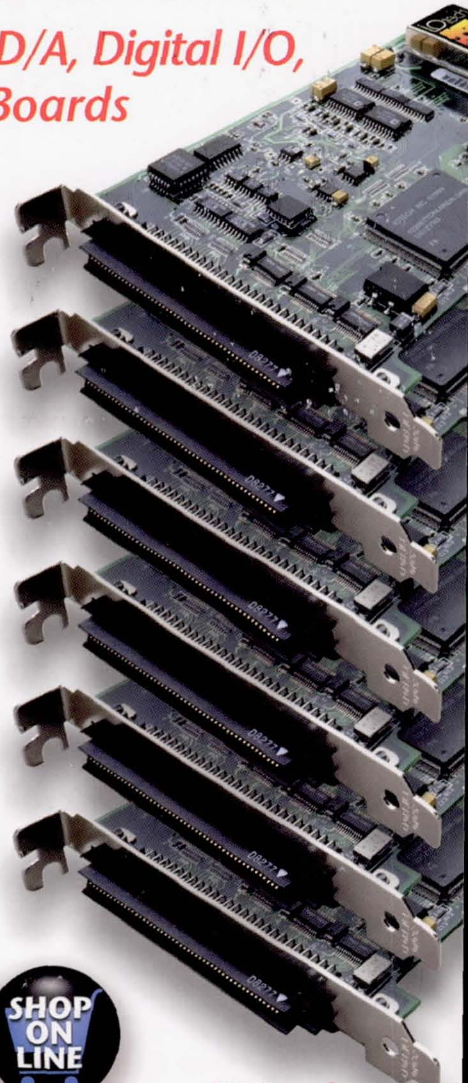

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Digital I/O	40	40	40	40	40	–
Frequency/pulse I/O	6	6	6	6	6	–
Signal conditioning options	27	27	27	5	5	–
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this type includes an optical fiber coated with an oxygen-conducting polymer matrix. Specific metal complexes that exhibit rapid and reversible binding of oxygen with associated changes in optical absorption spectra are immobilized in the polymer matrix. In operation, the coated fiber is immersed in water at a test site, and by use of optoelectronic components coupled with the optical fiber, the absorption spectrum of the metal complexes in the coating is measured. The absorption spectrum is then translated into the concentration of dissolved oxygen.

The absorption-measurement principle of the developmental fiber-optic sensors is compatible with a network of distributed sensors and results in lower costs of instrumentation.

This work was done by Michael Schwartz of Eltron Research, Inc., for **Kennedy Space Center.** *Inquiries should be addressed to Michael T. Carter, Eltron Research, Inc., 4600 Nautilus Ct. South, Boulder, CO 80301; telephone (303) 530-0263.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to the above. Refer to KSC-11999, volume and number of this NASA Tech Briefs *issue, and the page number.*

Gas Analyzer Measures Concentrations of H_2, O_2, and H_2O

This apparatus can help ensure safety in a system that handles liquid hydrogen.

John F. Kennedy Space Center, Florida

An apparatus measures small concentrations of H_2, O_2, and H_2O in flowing He gas. In the original application for which the apparatus was developed, the flow of He gas is used to purge a tube through which liquid hydrogen is transferred:

- The tube must be purged to remove water vapor and oxygen prior to the introduction of liquid hydrogen into the tube; hence, it is necessary to verify that O_2 and H_2O are no longer present in the purge gas before stopping this purge.
- Once the transfer of hydrogen through the tube is complete, the tube must be purged to remove hydrogen; hence, it is necessary to verify that H_2 is no longer present in the purge gas before stopping this purge.

The apparatus could also be used to measure concentrations of H_2, O_2, and/or H_2O in other cryogenic-liquid or gas systems.

The apparatus (see figure) includes H_2, O_2, and H_2O sensors; a sampling pump; flow controllers; a pressure transducer; a thermocouple; a computer; a display panel; and a modem. The H_2 and O_2 sensors can measure concentrations from 0 to 10 percent with accuracies of ±1 percent of their full-scale readings and can withstand sound and vibration conditions of a space shuttle launch. The H_2 sensor can operate at temperatures from −10 to +60 °C; the O_2 sensor can operate at temperatures from −10 to +40 °C. The H_2O sensor can measure concentrations from 125 parts per million (ppm) to 4 percent, with an accuracy of ±10 ppm at 125 ppm. The H_2O sensor can operate at temperatures from −10 to +40 °C.

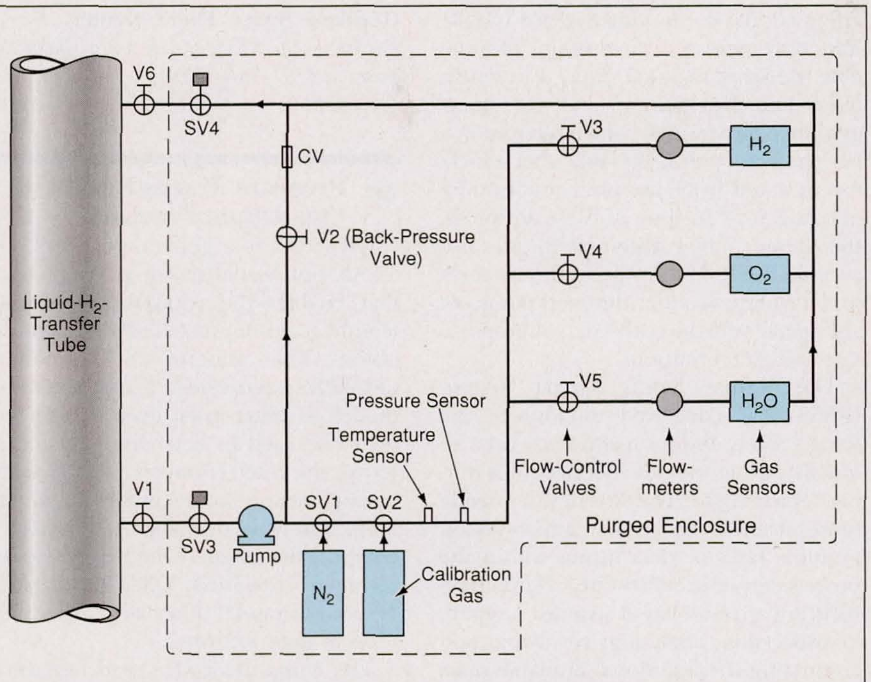
The computer, modem, and display panel are used to control the operation of the rest of the apparatus and to interpret the sensor readings. Control and monitoring tasks can be performed at a safe location, remote from the sensors and the gas system during hazardous operations (e.g., operations in which significant quantities of both hydrogen and oxygen could be present).

The apparatus can be isolated from, or connected to, the purged liquid-hydrogen-transfer tube by use of manual valves V1 and V6. Once these valves have been opened, the apparatus operates in the following sequence:

1. Solenoid valves SV3 and SV4 are opened.
2. The plumbing of the apparatus is purged with N_2 to remove traces of H_2O water vapor that may have leaked in.
3. After the N_2 purge, the sampling pump is started. The pump pulls a sample of gas from the liquid-hydrogen-transfer tube through SV3, then pushes through the flow-control valves, flowmeters, and gas sensors. After passing through the gas sensors, the sampled gas is returned through SV4 back into the liquid-hydrogen-transfer tube.

The apparatus continuously measures the concentrations of H_2, O_2, and H_2O; the rates of flow in the three sensor lines; and the pressure and temperature of the sample gas. All data are logged on a host computer and displayed at a control station. The apparatus can be calibrated from either a remote control station or from a control panel on the apparatus.

This work was done by Clyde F. Parrish, Christian J. Schwindt, Steven J. Klinko, and Timothy R. Hodge of Dynacs Engineering Co., Inc., for **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Test and Measurement category. KSC-12136*



The **Gas Analyzer** measures the concentrations of H_2, O_2, and H_2O in the liquid-H_2-transfer tube while the tube is undergoing a purge with He.

Software

Development of a Range-Safety Smart System

Range Safety Officers (RSOs) are used by NASA and other government agencies to assure protection of life and property during launch operations. The current decision-making system used by the RSOs at NASA Wallops Flight Facility (WFF) and the National Ranges, including the Eastern Range (ER) and Western Range (WR), was conceptually developed in the late 1960's and early 1970's. From time to time, improvements have been implemented to increase reliability. However, technology did not exist to make significant improvements in the 3-to-5-second RSO decision-making time. Today, it appears technically feasible to make significant improvements to this system.

Since the 1970's, advances in technology have significantly increased the amount of real-time data, produced low-cost high-speed computer systems, added new data sources, and produced "smart" guidance systems for launch vehicles. Today's telemetry systems provide large quantities of real-time data, which can be readily evaluated by new computer systems. These computer systems now have the processing power and software to perform real-time analyses at low cost, within the decision-making constraints of range safety. Global Positioning Systems (GPSs) have also increased the amount of available decision-making data. Currently, many launch-vehicle systems use smart guidance processors, which compute a new trajectory to orbit once the vehicle has deviated from the pre-launch nominal trajectory. In spite of these advances, the current range safety system does not provide the RSO with the optimum tools to determine whether deviated paths are abnormal vehicle paths or solutions to unexpected conditions.

The Range Safety Smart System (RSSS) was conceived to advance the Range Safety System technology used to make destruct/no-destruct decisions during vehicle flight. The system will provide more accurate and timely advisories on multiple tasks or data inputs within the range safety time constraints of launch vehicle and ground-based systems. A system of processing, analyzing, certifying, and comparing the additional available data, and presenting it to the RSO in a manner which does not add to his/her monitoring burden, will greatly enhance the quality of the real-time destruct/no-destruct decisions; additionally, it will reduce the probability of destructing a good vehicle, increase mission success, and reduce operational cost by reducing the number of RSO support personnel.

In October 1990, Research Triangle Institute (RTI) proposed to utilize computer thought-processing to evaluate real-time RSO decision-making data and present it in a manner that could reduce the RSO's real-time workload and reduce the number of support personnel. In response to this proposal, NASA initiated the RSSS effort. To date, the following have been completed: (1) System Definition, (2) Proof-of-Concept, and (3) Development of a RSSS Demonstration Model. The first two phases were performed by RTI. Phase III, Development of a Demonstration Model, was performed jointly by NASA WFF and RTI.

The demonstration model has been shown to various groups at NASA and DoD. The ER utilized some of the concepts demonstrated in the demonstration model in the Cassini mission. This technology may be adopted by other operational groups at NASA, DoD, and the private sector, who could benefit from its data-acquiring, analyzing, and advising capabilities.

This work was done by Jaya Bajpayee of **Goddard Space Flight Center**. *For inquiries on the RSSS, please contact Jaya Bajpayee at (301)286-0569.*
GSC-13860

Program Traces Rays With Quadruple Precision

QRAYPKS is a general-purpose FORTRAN optics-analysis computer program that enables the computation of path lengths to an unprecedented level of precision. The impetus for developing QRAYPKS was the need to mathematically model an outer-space laser interferometer to be used in detecting gravitational waves; the interferometer is expected to have a baseline about 5 million kilometers long, and it is necessary to be able to compute the length of the baseline to subpicometer precision. QRAYPKS can also be used to model other large optical systems in their entirety.

The computer codes used heretofore in designing lenses and other optical systems are capable of single- or double-precision arithmetic and are suitable for modeling of optical systems with dimensions up to a few meters, but double-precision arithmetic cannot, by itself, resolve path lengths to the subpicometer level over millions of kilometers. In principle, one could obtain the required precision from such a double-precision code by breaking a ray-tracing problem into multiple parts, each small enough that double precision would yield a meaningful result; however, this approach would be time-consuming and susceptible to error.

QRAYPKS is primarily a ray-tracing code: it traces user-specified rays through an optical system that consists of refractive and reflective elements. QRAYPKS can find the intercepts of rays with high-order aspherical surfaces in three dimensions. It can also perform diffraction analysis, approximating a diffraction integral as a sum.

The input to QRAYPKS for specifying an optical system is similar to the input to an optical-design computer program called "CODEV." The main output of QRAYPKS consists of distances along rays between optical surfaces. In addition, because QRAYPKS carries a local coordinate frame with each ray, one can utilize the coordinate frame as part of the basis of a polarization ray-tracing code.

QRAYPKS affords the required path-length precision through the use of quadruple-precision arithmetic. To take advantage of this capability, one must run QRAYPKS on a Digital Alpha (or equivalent) computer, the FORTRAN compiler of which supports quadruple-precision arithmetic. Preferably, the computer should contain integrated circuits capable of performing quadruple-precision arithmetic in hardware, because a software implementation of quadruple-precision arithmetic can multiply the computation time by a factor as large as 100. The machine ε (the smallest increment that, when added to 1, gives a result different from 1) in QRAYPKS is $\approx 10^{-32}$: This level of precision is more than adequate to resolve a subpicometer difference in path length over a multimillion-kilometer baseline.

This program was written by Eugene Waluschka of **Goddard Space Flight Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category. GSC-14362*

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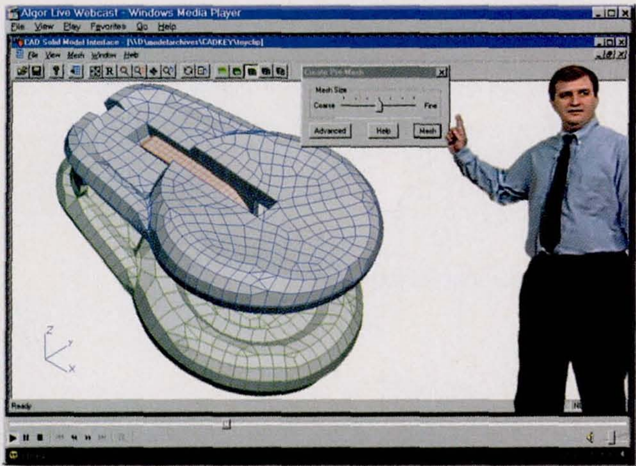

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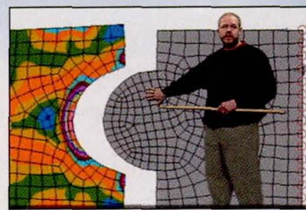

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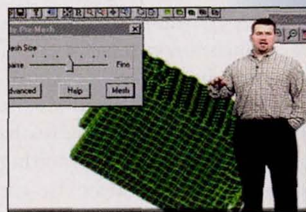

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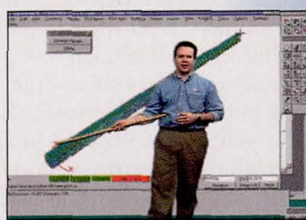

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Materials

Polyaniline Compounds for Protection Against Corrosion

Protective surface layers can be formulated and applied in various ways.

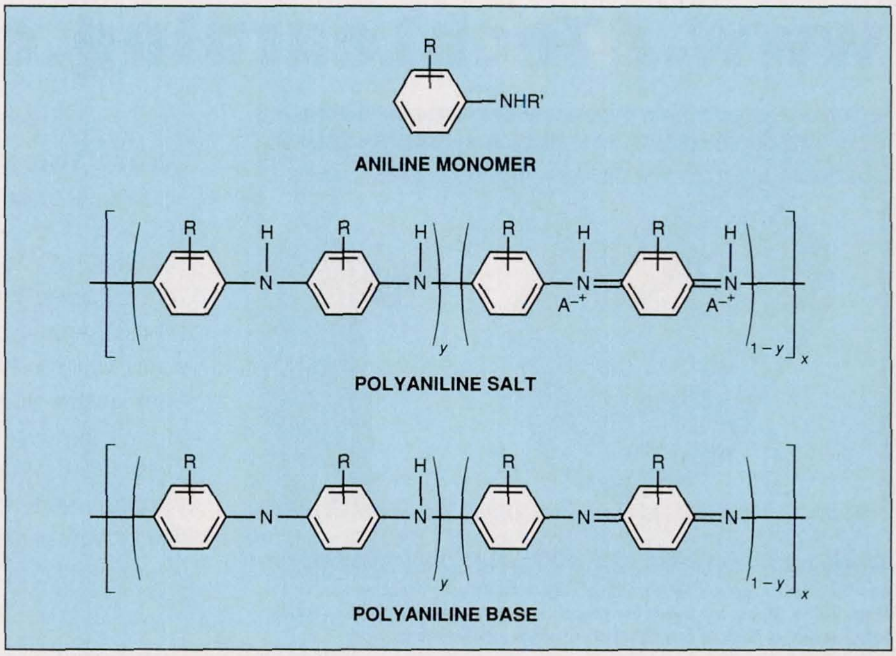
Lyndon B. Johnson Space Center, Houston, Texas

Corrosion of iron and steel substrates can be inhibited by coating them with any of the wide variety of compounds denoted generally as polyanilines. A polyaniline suitable for this type of application can be in either an electrically conductive salt (doped) form or an electrically nonconductive base form. Typically, polyaniline is dissolved in an organic solvent and the resulting solution is applied to a substrate by spraying, dipping, or brushing. The solvent is then allowed to evaporate leaving the substrate coated with a solid film of polyaniline, typically 1 to 200 µm thick.

The figure illustrates the general molecular structures of aniline monomers and polymers. In general, the synthesis of a polyaniline involves mixing an aniline monomer with a protonic acid (e.g., hydrochloric acid), and a polymerization agent in an aqueous medium. The mixture is stirred and maintained at a temperature that depends upon the specific formulation and is typically a few degrees above or below 0 °C. The polymer forms as a blue-green precipitate, which is collected.

The polyaniline precipitate is washed with a protonic acid and/or organic solvent to obtain a polyaniline salt with a molecular structure like that shown in the second part of the figure. If desired, the polyaniline salt can be treated with an aqueous base (e.g., ammonium hydroxide) to convert the salt to a base with a molecular structure like that shown in the third part of the figure. The resulting polyaniline base is preferably in an oxidation state associated with a form of polyaniline called "emeraldine." The polyaniline base can then be recovered by such established techniques as washing with an aqueous base and organic solvents, followed by vacuum drying.

Preferably, a coating solution is made from a polyaniline in the base form because of the relatively high solubility of the base form. Solvents that can be used to make polyaniline base solutions include dimethyl sulfoxide, N-methylpyrrolidinone, and tetramethylurea. The concentrations of polyanilines in useful coating solutions lie approximately in the range between 0.5 and 5 weight percent.



Aniline Monomers and Polymers exist in a variety of molecular structures. "R" and "R′" represent hydrogen and/or alkyl or alkoxyl functional groups containing between 1 and about 6 carbon atoms apiece, "A" represents an anion, and x is an integer. For each polyaniline, y and $1 - y$ ($0 \le y \le 1$) denote the proportions of the two types of groups depicted in parentheses; the position of each such group along the molecular backbone is shown for example only and is not known precisely in advance.

Upon exposure to a corrosive, acidic environment, a polyaniline coating film in base form undergoes a conversion to a doped, electrically conductive salt form. The polyaniline film coating can also be applied to the substrate in a partially doped form; however, the partially doped polyaniline is generally more difficult to dissolve in a given solvent. Useful dopant anionic species that can be used to make partially doped polyaniline coatings include sulfonic acids and camphor sulfonic acid; solvents that can dissolve the resulting partially doped polyanilines include toluene and substituted phenols.

The tenacity of a polyaniline coating can be increased by pretreating the surface of the substrate with a suitable compound. Compounds useful for this purpose are some that simultaneously bind chemically, via covalent or ionic bonds, to the surface of the substrate and to the polyaniline. Among these compounds are phosphoric acid, polyphosphoric acid, and organic chelating agents in which atoms form multiple coordinate bonds with the substrate.

This work was done by N. Ahmad and A. MacDiarmid of the University of Pennsylvania for **Johnson Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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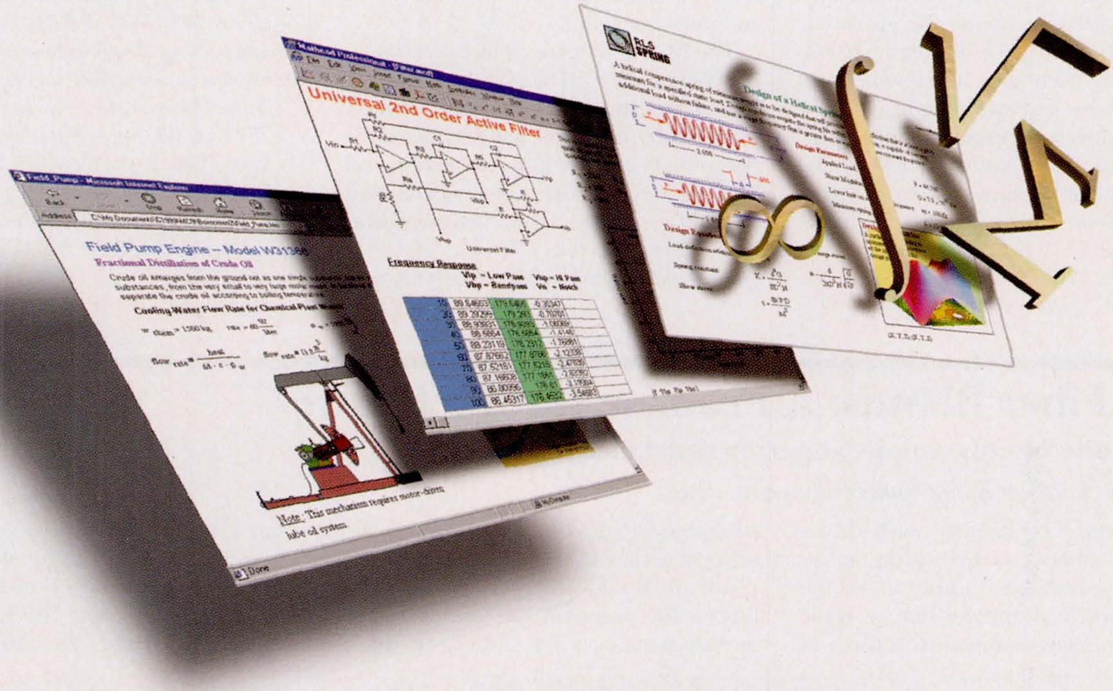

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For More Information Circle No. 502

Improved Coatings for Flexible Insulating Blankets

These materials offer increased resistance to erosion.

Lyndon B. Johnson Space Center, Houston, Texas

"ACE" (for "advanced ceramic engineered") denotes a type of coating material that increases the ability of flexible thermal-insulation blankets to resist erosion. Developed for use on the insulating blankets on the space shuttle orbiters, these coating materials could also be used on similar terrestrial insulating blankets on aircraft, engine, and furnace components.

ACE coatings are available in two varieties; a white reflectance coating or a gray emittance coating. The white variety is formulated with (1) a binder of tetraethylorthosilicate (TEOS), which is a polymeric precursor to silica and (2) a filler of high-purity silica powder. The gray variety is formulated with the same binder and filler, but also contains silicon carbide as an emittance agent.

The ACE coatings are similar to a coating material called "C-9" that has been used on the space shuttle insulating blankets. (The binder in C-9 is a colloidal silica.) In preliminary rain erosion tests and in consecutive radiant-heat and air-jet erosion tests, ACE coatings resisted erosion better than C-9 coatings did.

This work was done by Mary M. Fleming and Gordon R. Toombs of Rockwell International Corp. for **Johnson Space Center.**

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act {42 U.S.C. 2457(f)}, to Rockwell International Corp. Inquiries concerning licenses for its commercial development should be addressed to

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Refer to MSC-22495, volume and number of this NASA Tech Briefs *issue, and the page number.*

PBO Fiber Blends: A Promise for the Future

At least one blend exhibits superior resistance to abrasion.

Lyndon B. Johnson Space Center, Houston, Texas

Woven fabrics comprising polybenzoxazole (PBO) fibers blended with other selected fibers have been found to exhibit combinations of properties that, in some applications, may be superior to those of fabrics made from either PBO alone or the other materials alone. This finding is the result of an investigation of improved fabrics for potential use in space suits and in structures for protecting spacecraft against micrometeoroids. Potential terrestrial applications for the improved fabrics could include bulletproof vests, protective suits for firefighters, and lightweight armor for military equip-

Description of Specimen	Tensile Strength Before Abrasion, lb.	Strain, Percent	Energy to Break Point, in.-lb.	Tensile Strength After Abrasion, lb.	Percent Loss of Tensile Strength	LOI, Percent O_2
40 % PBO, 60% Polyimide Hybrid, Plain Weave	3,527	10.57	3,655	1,199	65	51
60 % PBO, 40% Polyimide Hybrid, Plain Weave	4,528	9.25	4,783	1,600	65	56
Pure PBO, Plain Weave, 500 Denier	6,662	11.42	9,216	2,197	67	74
Pure PBO, Double Cloth, 500 Denier	7,890	13.91	12,480	3,930	50.2	75
Aromatic Polyimide, Plain Weave, 1,500 Denier	3,739	8.541	3,772	327.8	91.2	37
PBO/Aramid Felt-PBO (Inside) Aramid Felt Triple Cloth	5,631	6.956	6,002	2.972	47	40

PBO Fiber Blend Test Data shows enhanced abrasion resistance and other similar properties versus PBO alone and polyimide alone.

ment and personnel, as well as tethers for parachutes or aircraft.

PBO is characterized by high values of thermo-oxidative stability and tensile strength — a combination of properties that make PBO desirable for many applications, including those described above. However, PBO exhibits some of the same deficiencies — in particular, limited flex life and limited resistance to abrasion — observed in other high-modulus fiber materials. Therefore, woven fiber blends with PBO were investigated in an effort to increase flex life and resistance to abrasion without sacrificing tensile strength or resistance to flames and heat.

In the investigation, enhanced performance was sought through changes in the structures of yarns and fabrics through blending PBO multifilament yarns with other high-performance filamentary materials. Specimens in the form of webs 2 in. (≈5.1 cm) wide were made from PBO and other materials as follows:

- A plied (double-cloth) fabric consisting entirely of PBO (one of two control specimens);
- A plain-weave fabric consisting entirely of PBO;
- A plied fabric consisting entirely of Kevlar aromatic polyamide (the other control specimen);
- A plied yarn hybrid of which 60 percent consisted of PBO fibers and 40 percent consisted of high-temperature-resistant, wear-resistant polyimide fibers known by the trade name "P84";
- A plied yarn hybrid consisting of 40-percent PBO and 60-percent P84 polyimide; and
- A hybrid fabric consisting of 70-percent PBO and 30-percent Nomex aramid felt.

The specimens were abraded according to a Federal specification for testing for resistance to abrasion. The specimens were tested for tensile strength before and after abrasion. They were also evaluated with respect to limiting oxygen index (LOI) (a measure of resistance to burning).

The table presents some of the data from the tests. The PBO/Nomex-blend specimen resisted abrasion better than did the pure-PBO specimen. Although the LOIs of the blend specimens were less than those of the pure-PBO specimens, they were still much higher than that of any other commercially available polymer fiber fabric of the same density. The LOIs of all samples tested satisfy the flame-resistance requirements for use in the space-shuttle cabin, which is an indication that PBO fiber blends have great potential for spacecraft applications.

This work was done by Evelyne Orndoff of **Johnson Space Center**, *Steven Clarke of Albany International Research Co., and Rajib Dasgupta of Lockheed Martin. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category. MSC-22957*

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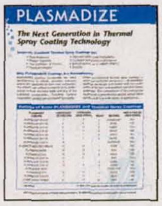

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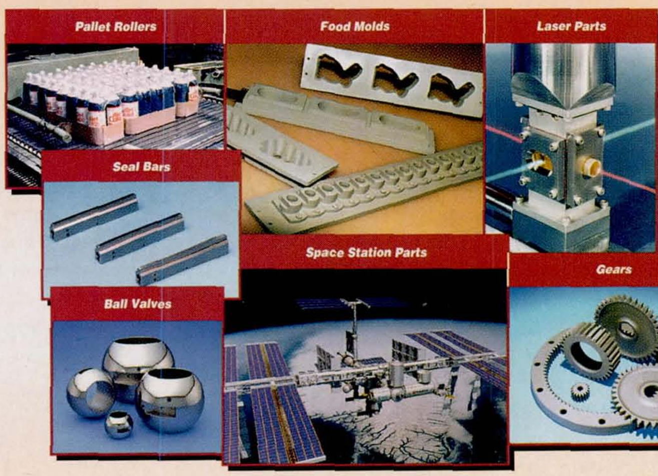

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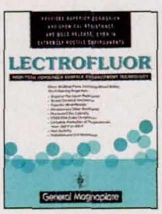

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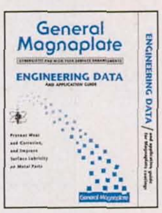

Engineering Data Guide

New, 8-page Engineering Data and Application Guide details technical information on 13 surface enhancement coatings for metal parts. The following tech-data for each coating is easily identified: description, hardness, resistance to wear and abrasion, corrosion resistance, thickness, friction properties, dielectric and thermal properties, and applications. Many examples of parts, which were treated with a Magnaplate coating to solve a customer's problem, are also shown.

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Mechanics

Air-Displacement Volumometer With Soft Sides

Complete submersion of the subject in water is no longer necessary.

Lyndon B. Johnson Space Center, Houston, Texas

An air-displacement volumometer with soft sides has been devised for measuring the volume of a human body. This apparatus could be useful in hospitals, medical research laboratories, clinics, athletic facilities, and the like. It could also be used to measure the volumes of irregularly shaped objects with dimensions comparable to those of a human body.

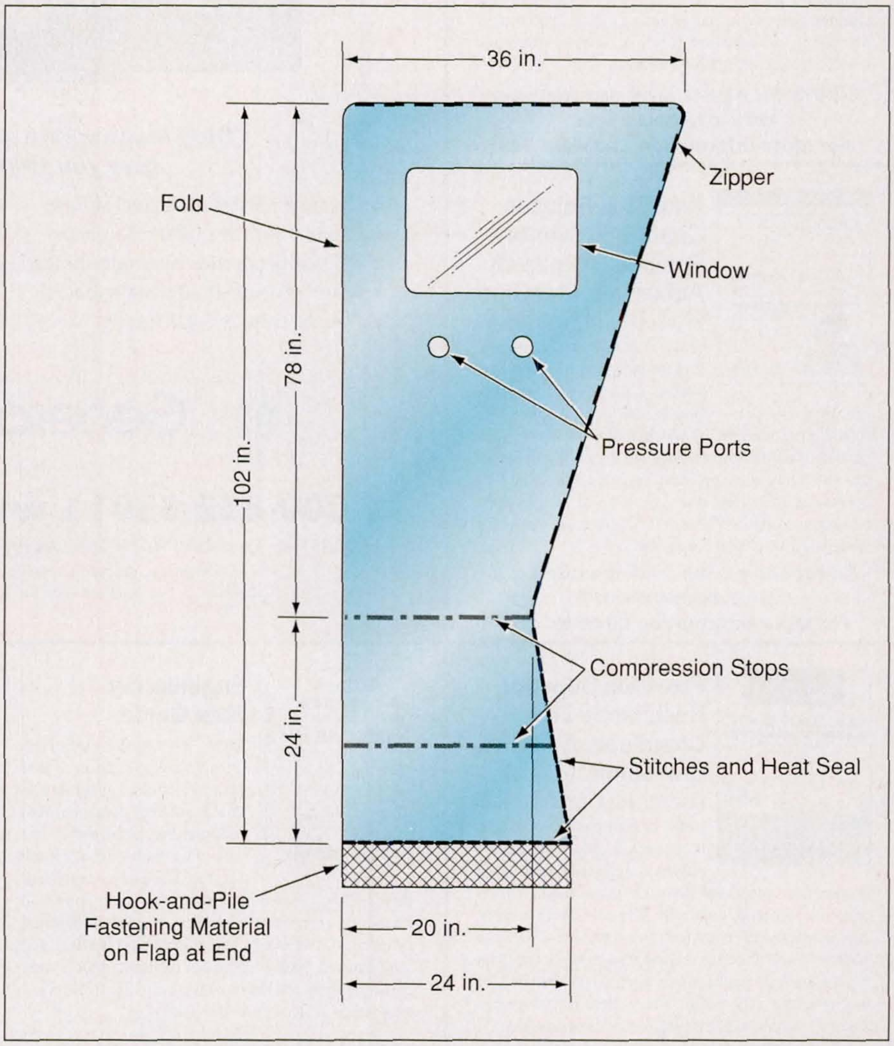
The traditional procedure for measuring the volume of a human body is based on the Archimedean principle of weighing the subject in air, then weighing the subject underwater, then equating the volume of the subject to the volume of water displaced, as indicated by the difference between the two weight measurements. In this procedure, the subject is required to exhale totally, hold his or her breath, and submerge totally in water. The traditional procedure is obviously not suitable for subjects who are hydrophobic or averse to total exhalation.

The use of air-displacement volumometers does not involve immersion, and total exhalation is unnecessary. Air-displacement volumometers with hard sides were used during the early 1960s, but were abandoned because they gave relatively inaccurate results (±5 percent). Moreover, hard-sided air-displacement volumometers were large and not portable. The present soft-sided air-displacement volumometer gives relatively accurate results (±0.15 percent) and is portable.

The soft-sided air-displacement volumometer consists mostly of a hermetic bag with pressure ports and a hermetically sealing zipper (see figure). The bag is also marked with two compression stops; these are lines to which the lower end of the bag is rolled to provide compression to a sequence of known volumes. The measurement procedure is as follows:

1. The subject enters the bag, which is then zippered shut.
2. The bag is inflated to a gauge pressure of 10 cm H_2O (0.98 kPa).
3. The subject is asked to hold his or her breath during the next step.
4. The bag is rolled up to the first compression stop and held there momentarily, then rolled up to the second compression stop. The pressure is recorded continuously during this compression process.
5. The subject is instructed to breathe.
6. Steps 2 through 5 are repeated four more times to obtain a total of five trials, each involving a sequence of three pressure measurements (the initial inflation pressure and the pressures at the two compression stops).

Using the ideal-gas law, one calculates the volume of the person or irregular object in the bag from the nominal empty-bag volumes and corresponding pressure readings at initial inflation and the two compression stops for each trial. The calculated volumes are then averaged over the five trials. The results of these calculations are independent of the elasticity of the bag, provided that the elasticity of the bag remains constant over the small ranges of pressure and volumes used in the measurements.



The **Bag Is Zipped Shut With a Person Inside**, then inflated slightly, then rolled up to the compression stops in sequence, all the while recording the pressure in the bag. The volume of the person can be computed from the pressure readings and the nominal (zero-pressure) empty-bag volumes.

This work was done by Steven F. Siconolfi of **Johnson Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*

This invention has been patented by NASA (U.S. Patent No. 5,948,977). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-0837. Refer to MSC-22653.

Improved Methodology for Dynamics of Orbiter Payload Bay Doors

Lyndon B. Johnson Space Center, Houston, Texas

The Payload Bay Door Dynamics Simulation (PBDS) computer program simulates the mechanical behavior of the space-shuttle payload bay doors and their latching and driving mechanisms during opening, closing, latching, and unlatching. PBDS was developed to replace an older program that was computationally inefficient and that simulated the door hinges incorrectly. In PBDS, the large system of dynamical equations of the payload-bay-door system is decomposed into smaller systems of dynamical equations at the mechanism level. This decomposition involves decoupling through neglect of the inertial parameters of the driving and latching mechanisms, which are small relative to those of the doors. The equations of motion of the doors, which are flexible, are derived by use of a Cartesian flexible-body formulation. The equations of motion of the mechanisms are derived by use of an efficient recursive formulation. Though decoupled dynamically, the door and the mechanisms are coupled kinematically. In solving the mechanism equations, the responses of the door at points where the door is attached to the mechanisms are fed as inputs to the mechanism equations. The outputs of the mechanism equations are forces and torques, which are fed back to the door equations to complete the computational cycle.

This work was done by Shih-Chin Wu of Boeing North American, Inc., for **Johnson Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category. MSC-22845*

Machinery/Automation

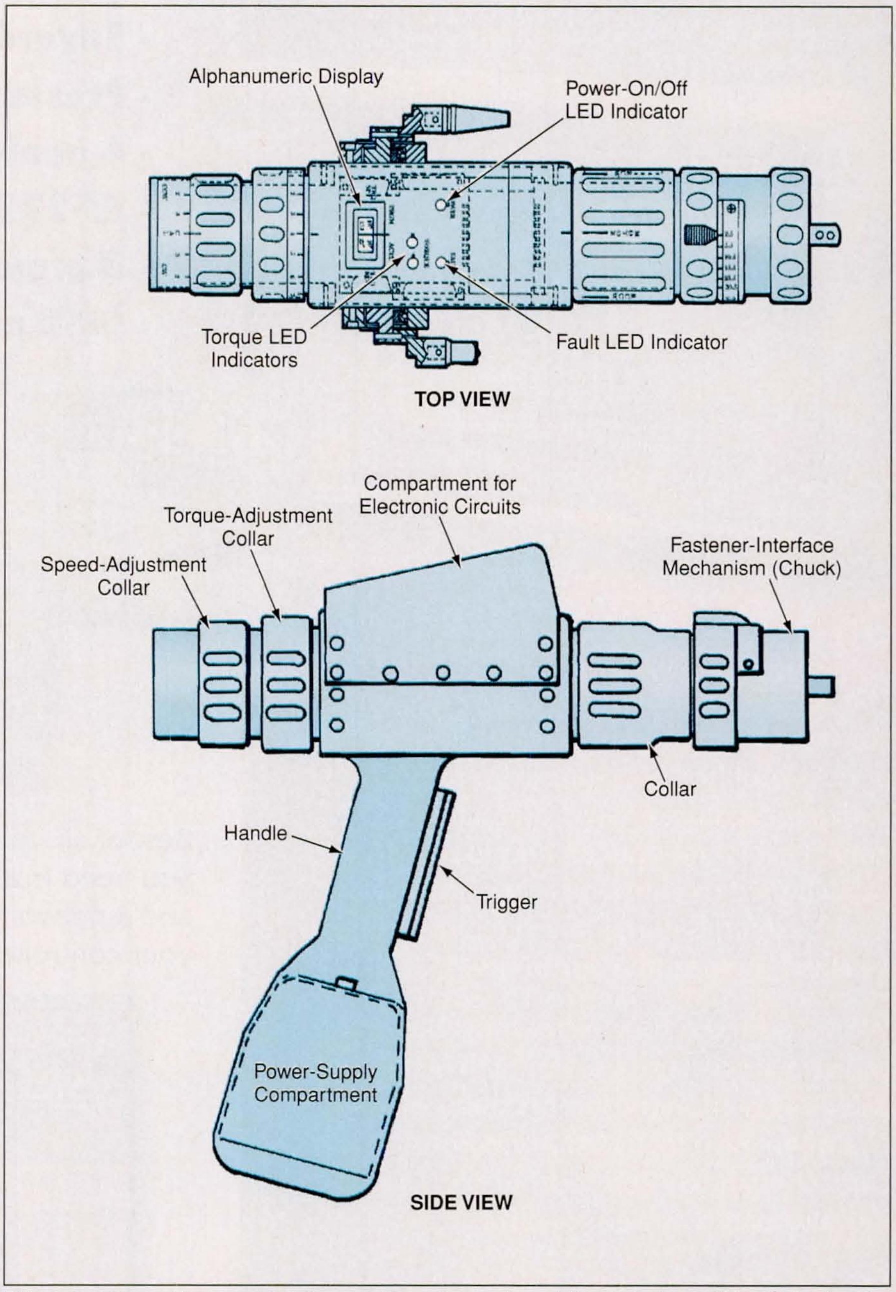
Computer-Controlled Power Tool

Torque or speed is regulated, and operational history can be analyzed.

Goddard Space Flight Center, Greenbelt, Maryland

The figure depicts the exterior appearance of a pistol-grip rotary power tool that can be used to turn a drill bit, wrench socket, screwdriver, or other tool bit clockwise or counterclockwise at a controlled speed or torque. This tool is an updated version of the one described in "Pistol-Grip Torques-Measuring Power Tool" (GSC-13706), *NASA Tech Briefs*, Vol. 23, No. 7 (July 1999), page 36. Like other tools that it superficially resembles, it contains an electric motor drive powered by either a battery or a power-supply circuit with a standard power-line connection. Unlike other such tools, this tool also contains the following:

- Torque and temperature sensors;
- Shaft-rotation pulse-counting and timing circuitry for measuring speed;
- External controls for setting the mode of operation, the direction of rotation, and the desired value of speed or torque;
- An onboard computer that generates its own timing signals and monitors and controls the overall operation of the tool;
- A drive circuit through which the onboard computer controls the electric current applied to the motor;
- An alphanumeric display for use in programming and monitoring operational parameters;
- Light-emitting-diode (LED) torque, power-on/off, and fault indicators; and
- A port for communication between the onboard computer and an external computer.



This **Rotary Power Tool** superficially resembles other such tools but includes additional circuitry, including an onboard computer, that provides enhanced capabilities for control of speed and torque, detection of faults, and analysis of operation.

In the customary manner, the operator of the tool presses a trigger to put the tool in a running state and releases the trigger to put the tool in an idling state. During operation, the digital outputs of the torque and temperature sensors and of the speed-measuring circuitry are presented to the onboard computer. The software in the onboard computer implements an interrupt-driven state machine for the purposes of monitoring operational parameters, controlling speed or torque, keeping a history of operation, and communicating with the external computer.

The history of operation includes records of two types: (1) data on torque and shaft angle as functions of time during the tightening and/or loosening of fasteners; and (2) records of events (e.g., turn-on of power or

overheating). These records are stored in non-volatile memories in the onboard computer. The onboard and external computers communicate with each other for the purpose of transferring these records so that the external computer can be used to analyze operation and/or to modify operational parameters. Operational parameters can be transferred from the external computer to a nonvolatile memory in the onboard computer; thus, in effect, the external computer can program and remotely control the tool.

This work was done by Kenneth W. Wagner, James C. Taylor, and Paul W. Richards of **Goddard Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*

This invention has been patented by NASA (U.S. Patent No. 5,903,462). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center; (301) 286-7351. Refer to GSC-13879.

Technique for Controlling Gas Generation in a Bioreactor

In the reactor, bubbles are suppressed by pressurizing the liquid flowing through it.

Lyndon B. Johnson Space Center, Houston, Texas

A pressure-swing technique has been developed for controlling the generation and flow of gas in an anaerobic biological reactor and associated equipment in a system that processes wastewater. The purpose and effect of the technique is to prevent the formation of gas bubbles in the reactor; if allowed to coalesce in the reactor, gas bubbles could impede the flow of the liquid stream, rendering the treatment system less effective. The technique was conceived for application to a wastewater treatment system that would operate in microgravity, but could also be applied to bioreactor systems (e.g., fermentation systems) that operate in Earth-normal gravity.

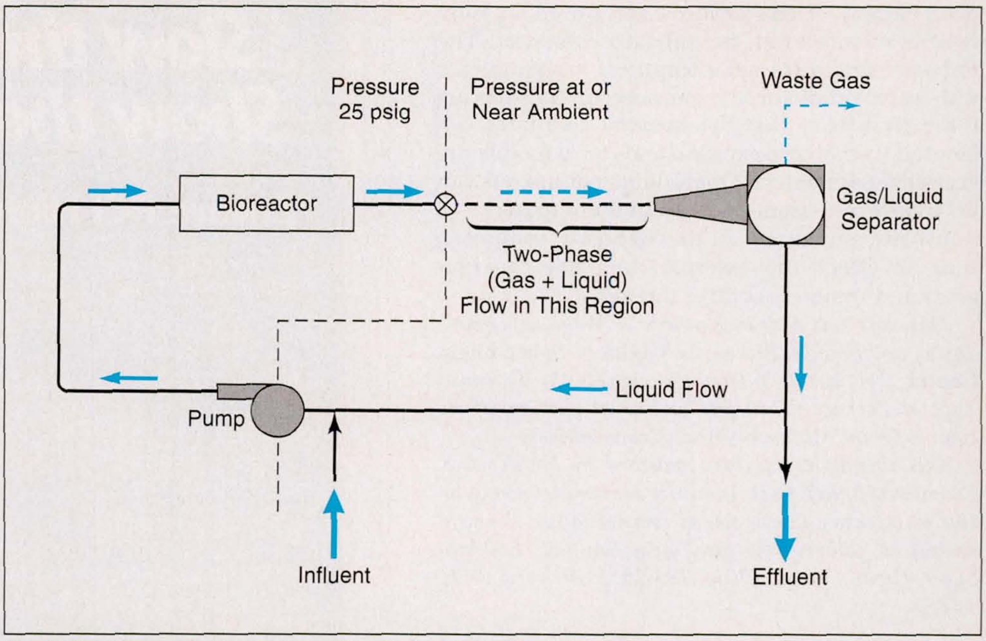
A representative system that implements the present technique (see figure) includes a packed-bed reactor that is inoculated with anaerobic micro-organisms, a gas/liquid separator, a pump, a back-pressure relief valve, and associated plumbing and other hardware. Wastewater is fed into the system at a constant rate, and effluent is removed from the system at the same rate, both at a pressure near ambient. The pump pressurizes the water to 25 psig (gauge pressure of 172 kPa) and circulates the water through the bioreactor at a rate of 20 times the influent/effluent rate. After passing through

the reactor, the water flows through the back-pressure relief valve and is thereby depressurized to near ambient pressure.

In the reactor, the pressure is high enough to keep all gases in solution; this includes gaseous waste products generated by micro-organisms through their metabolism of contaminants in the wastewater. The depressurization causes the gaseous waste products generated in the reactor to evolve into gas bubbles. The resulting two-phase mixture flows into a gas/liquid separator. The separated gases are vented to the atmosphere, and the separated liquid travels to the pump, where it is repressurized for the next pass through the reactor.

The design size of the reactor is based on the desired rate of flow and the anticipated daily contaminant loading of the wastewater to be treated. The reactor pressure and the ratio between the recirculating flow and the inlet or outlet flow could differ from the values stated above; for a given application, they are calculated to maintain gases in solution in the bioreactor. In general, the use of a higher pressure makes it possible to reduce the liquid recirculation rate.

This work was done by Karen D. Pickering and Eugene K. Ungar of **Johnson Space Center.** *For further information, access the Technical Support Package (TSP) **free on-line at www.nasatech.com** under the Machinery/Automation category.*
MSC-22987



The **Higher Pressure** in the portion of the flow path that includes the bioreactor keeps gases in solution. The lower pressure in the portion of the flow path that includes the gas/liquid separator allows gases to come out of solution.

Physical Sciences

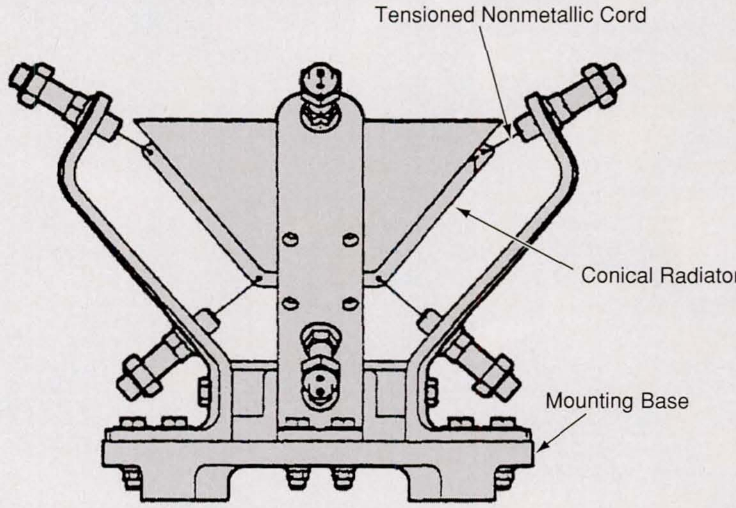
Passive Radiative Cooler for Use in Outer Space

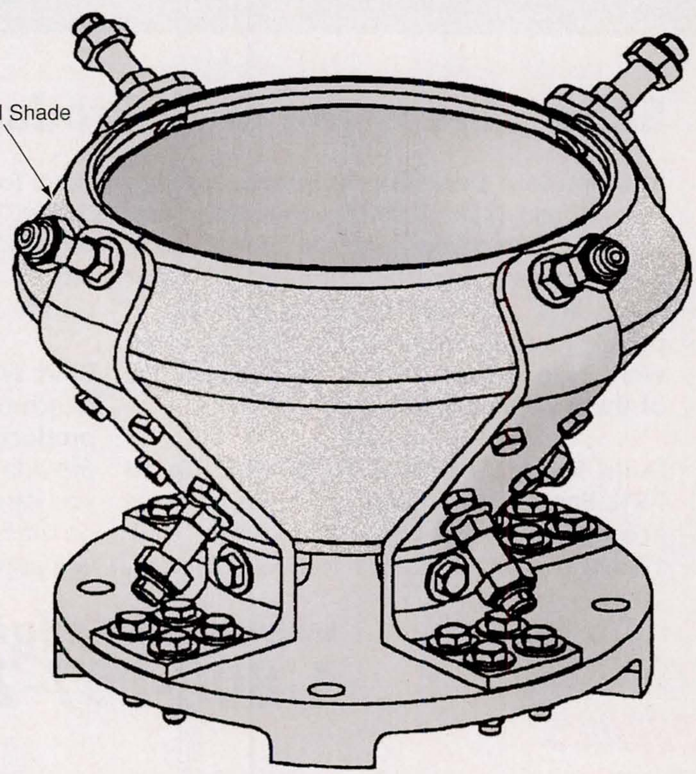
High-temperature superconductors are cooled radiatively to operating temperatures.

Lyndon B. Johnson Space Center, Houston, Texas

The figure depicts a passive radiative cooler designed for use in outer space. The design of this device conjoins radiative and conductive thermal-isolation features, which, in further conjunction with a favorable spacecraft attitude and on-orbit thermal environment, can be utilized to cool specimens of high-temperature superconducting materials to operating temperatures. Once installed on a spacecraft or even on the lunar surface, the passive radiative cooler will perform the cooling function that would otherwise be performed by a more expendables-hungry cryogenic system. This device, which has the added advantage of no moving parts, can operate in low orbit around the Earth in the space-shuttle cargo bay. Small and adaptable to many spacecraft and mounting configurations, this device can be used to demonstrate applications that involve superconductivity. Commercially, this device can advance the art by providing a simplified alternative for satellites equipped with infrared (IR) detectors or apparatuses that exploit superconductivity.

The current art in cooling sensors or specimens of superconducting or other materials in outer space involves the use of cryogenic cooling systems; the operation of such systems is more complex and certainly more costly in expendables (cryogenic fluids) than is the use of the passive radiative cooling capability of outer space itself. Though radiative coolers other than the present one have been used before in outer space, those devices can operate only on interplanetary spacecraft, on spacecraft in high orbit around the Earth, or on spacecraft in low orbit around the Earth under tailored illumination conditions (i.e., Sun-synchronous orbits). The thermal-radiation environment of a high orbit around the Earth differs markedly from that of a low orbit around the Earth: the proximity of the Earth gives rise to undesirable heating by IR radiation from the Earth plus reflected solar radiation reflected from the Earth (albedo) from a large portion of the field of view. The present passive radiative cooler provides shield-





This **Passive Radiative Cooler** shields a sample from infrared radiation incident from large off-axis angles while allowing infrared radiation to escape to space at angles closer to the axis.

ing against the radiation from the Sun and Earth and is of a size and simplicity that make it suitable for operation in the space-shuttle cargo bay, which is also a source of IR heating.

The three main components of the passive radiative cooler are a mounting base, a conical shade, and a conical radiator/sample tray. The mounting base includes a low-thermal-conductance structure for holding the conical shade. The conical radiator is suspended within the conical shade by tensioned nonmetallic cords, which provide (1) a high degree of isolation against thermal conduction and (2) protection against vibration for the sample tray and the radiator. Both the outside of the conical radiator and the inside of the conical shade are fabricated with a low-IR-emittance finish for a high degree of radiative isolation. The inside of the conical radiator is given a high-IR-emittance finish to promote high radiative transfer of heat to space.

An item that one seeks to cool (e.g., a specimen of a high-temperature superconductor) is affixed to the sample tray, and the passive radiative cooler is mounted on a spacecraft structure that faces away from the Sun or a planet. As the spacecraft orbits in a specified attitude, the sample tray and sample are cooled radiatively. The cone angle of the radiator is chosen to afford adequate radiative heat rejection while enabling the cone to shield the sample from viewing other bodies (the Earth, the Sun, or nearby objects) that could adversely affect heat balance of the sample.

A relatively high degree of thermal isolation can be achieved. For example, in a test of a prototype of the passive radiative cooler, a sample temperature of 116 K was achieved in the presence of a mounting surface at a temperature of 240 K.

The passive radiative cooler is expected to function within a remarkable temperature range. The basic passive-radiative-cooler design is flexible and scalable; for example, if the device is to be mounted in a location with few nearby obstructions, it could be beneficial to design for a more open cone. The passive radiative cooler can be mounted on a spacecraft for cooling samples of high-temperature superconductors or other materials, detectors, or sensors, provided the environment and spacecraft attitude meet the specified criteria. Finally, again assuming that sufficient isolation from the surface can be achieved, the passive radiative cooler can even be used on the lunar surface to cool sensors.

This work was done by Steven L. Rickman, Ross G. Iacomini, David S. McCann, Robert G. Brown, and Yuan-Chyau Chang of **Johnson Space Center** *and by Jeffrey A. Clayhold, Ching-Wu (Paul) Chu, Allen W. Linnen, Jr., and Yuyi Xue of the Texas Center for Superconductivity, University of Houston.*
MSC-22712

Magnetically Enhanced Propellant Isolator for Ion Sources

A magnetic field inhibits the diffusion of electrons.

John H. Glenn Research Center, Cleveland, Ohio

A magnetically enhanced, high-voltage propellant isolator has been conceived for incorporation into materials-processing or space-based ion systems. The high-voltage isolator is needed to provide electrical isolation between the ion source, typically at high voltage, and the gas-feed system.

Heretofore, it has been the usual practice to provide the required electrical isolation by installing ceramic breaks (section of ceramic tubes) between grounded gas-feed lines and the high-voltage plasma source, as shown in the upper part of Figure 1. Unfortunately, at operating pressures between 13 Pa and 13 kPa and kilovolt potentials, the short ceramic spacer can often fail due to electrical breakdown of the feed gas, thereby causing a highly conductive plasma discharge to form inside the ceramic. Such breakdowns effectively short the ion source to near ground potentials, thus preventing high-voltage operation.

A magnetically enhanced, high-voltage isolator, as shown in the lower part of Figure 1, consists of a conventional ceramic isolator immersed in a strong transverse magnetic field. The strong, transverse field is provided by commercially available rare-earth magnets. The magnetic field increases the breakdown voltage at a given isolator internal pressure, thereby widening the range of operating conditions over which breakdown does not occur.

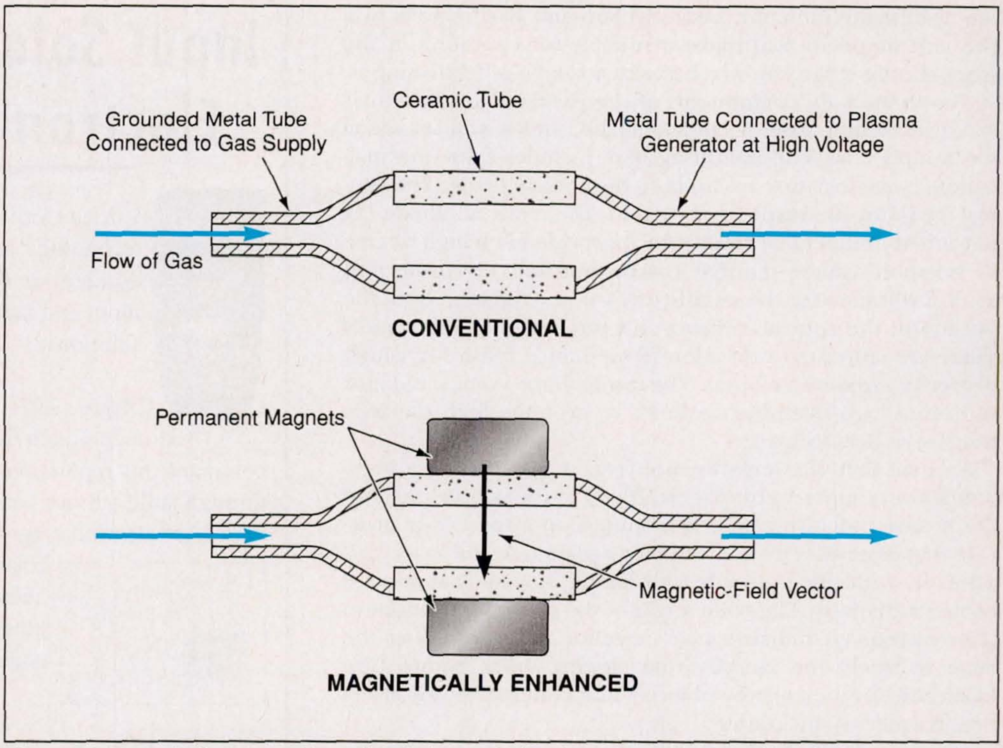


Figure 1. A **Magnetically Enhanced Propellant Isolator**, which isolates the gas-feed line from the ion source, is basically a conventional isolator tube sandwiched between permanent magnets that generate a strong, transverse field.

The primary purpose of the magnetic field is to severely restrict the motion of electrons parallel to the axis of the isolator. To first approximation, electrons are constrained to move in circles about magnetic-field lines and can diffuse across the transverse field only by collision with neutral molecules or ions. To inhibit the diffusion of electrons along the axis so as to prevent avalanche formation and breakdown, the magnetic field must be strong enough such that the electron cyclotron frequency (which is proportional to the magnetic-field strength) greatly exceeds the frequency of collisions between electrons and neutrals.

A prototype magnetically enhanced isolator was constructed by placing rare-earth magnets on opposite sides of a conventional isolator. The transverse magnetic field associated with this configuration was 2.6 kG on centerline. In tests at various gas pressures, the breakdown potential of the magnetically-enhanced isolator were found to exceed those of the same isolator without magnetic enhancement (see Figure 2). The greatest increase in breakdown potential was achieved at low pressures; this was expected because under those conditions, electron motion is sufficiently magnetized due to the lower electron-neutral collision frequency.

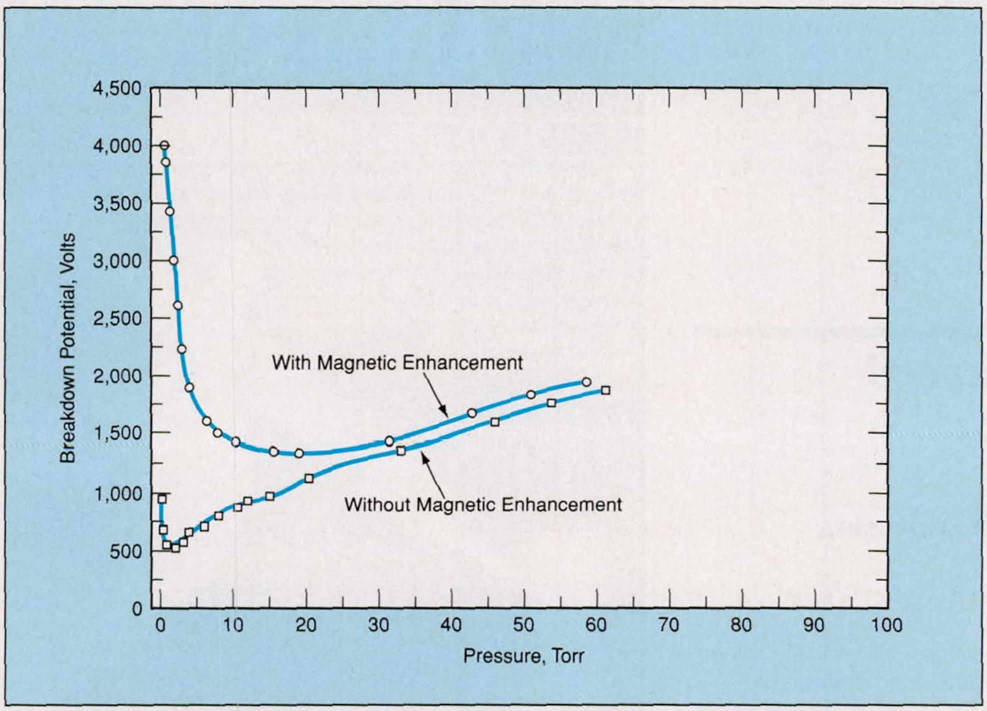


Figure 2. The **Breakdown Potential** applied between the ends of a prototype isolator tube similar to that of Figure 1, with and without magnetic enhancement, was measured as a function of xenon gas pressure. These plots have the form of typical Paschen breakdown curves.

This work was done by John E. Foster of **Glenn Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16749.

Buoy Instrumented for Spectral Measurement of Water Quality

John F. Kennedy Space Center, Florida

An instrumented buoy measures selected aspects of the spectrum of upwelling light for assessment of "water quality." The buoy carries a previously patented optical-backscatter probe that contains a hyperspectral sensor. The output of the probe is processed by a small onboard computer. Cellular-telephone circuitry on the buoy transmits spectral-signature data to a computer system that, in turn, makes the data available immediately over the World Wide Web. Power is supplied by gel batteries charged by a solar photovoltaic panel on top of the buoy. The scalable optical-backscatter probe is a scalable module fabricated separately from the buoy and the other equipment described above; the buoy and the other equipment are designed to accommodate and mate with the optical probe. Optionally, the instrumentation on the buoy can be augmented by incorporation of additional sensors (e.g., a pH sensor current meter). The current version of the buoy is not intended to function in the presence of high wind and waves; it is designed primarily for operation under relatively calm-sea conditions in shallow, semienclosed natural bodies of water (ponds, lakes, lagoons).

This work was done by Charles Bostater of Florida Institute of Technology for **Kennedy Space Center.** *For further information, please contact http://www.ocn.fit.edu/buoy.*
KSC-12053

Magnetostrictive Heat Switches Actuated by Flux Tubes

A switch would remain "open" or "closed" until actuated to change its state.

NASA's Jet Propulsion Laboratory, Pasadena, California

In a proposed improvement on the basic concept of a magnetostrictive heat switch for cryogenic applications, the magnetic field needed for actuation would be generated by a superconducting flux tube (SFT). A closely related concept for a magnetostrictive heat switch was presented in "Magnetostrictive Heat Switch for Cryogenic Use" (NPO-20274), *NASA Tech Briefs,* Vol. 23, No. 8, (August, 1999), p.48. To recapitulate: The main thermal contact in the heat switch would be made or broken by making or breaking, respectively, the mechanical contact between (1) the moving end of a rod of magnetostrictive material and (2) a fixed contact pad. The magnetic field needed for actuation would be generated by use of a superconducting solenoid.

The use of an SFT instead of a superconducting solenoid would be a significant and advantageous departure from the earlier proposal. In the case of a solenoid, it would be necessary to supply current continuously to the solenoid to maintain the magnetic field needed to keep the switch in either the "open" or "closed" state; turning off the current in the solenoid would cause the switch to revert to the opposite state. In contrast, in the case of an SFT, the magnetic flux would remain constant without power applied (other than the separate power needed in any event to maintain the cryogenic environment). Thus, an SFT-actuated heat switch would be bistable; it would remain in either the "open" or "closed" state until toggled into the opposite state. Toggling would be effected by applying a pulsed current to a coil

around the SFT to change the magnetic flux and thereby change the degree of magnetostriction.

In comparison with externally actuated mechanical and gas-gap heat switches, both the superconducting-solenoid SFT-type magnetostrictive heat switches would offer the advantage of less heat leakage. Both magnetostrictive heat switches would function at the temperatures of the devices to be thermally switched, with little or no thermal hysteresis. The switching time of either magnetostrictive heat switch would be only about one thousandth of that of a gas-gap heat switch. The SFT-actuated switch would offer the additional advantage that in the steady state, any thermal disturbance that it would introduce would be almost unmeasurably small and, in most cases, completely negligible.

SFTs made of bismuth strontium calcium copper oxide (BSCCO) are already available. Typical lengths and outer diameters are of the order of centimeters, and bore diameters range upward from 1 cm. Flux densities range from 0 to 10 T in the approximate temperature range from 77 K (liquid nitrogen) to 4 K (liquid helium). These flux densities are more than adequate for a magnetostrictive heat switch; the range of flux densities for magnetostrictive materials that have been investigated for use in heat switches is 0 to 0.2 T in the given temperature range.

This work was done by Robert Chave of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-20502

Magnetostrictive Valves Actuated by Flux Tubes

Power would be applied during toggling only.

NASA's Jet Propulsion Laboratory, Pasadena, California

Magnetostrictive valves for cryogenic applications would be actuated by superconducting flux tubes (SFTs), according to a proposal. The reasoning behind this proposal closely tracks that of the proposal to use SFTs in magnetostrictive heat switches, as reported in the preceding article.

Previous versions of magnetostrictive valves for cryogenic applications were described in "Magnetostrictive Valve for Use at Low Temperature" (NPO-19480), *NASA Tech Briefs*, Vol. 21, No. 2 (February 1997), page 14b and "Improved Magnetostrictive Valve for Use at Low Temperature" (NPO-20271), *NASA Tech Briefs*, Vol. 23, No. 8 (August 1999), page 48. As in magnetostrictive heat switches, the actuators in magnetostrictive valves are magnetostrictive rods, and actuation is effected by turning magnetic fields on or off.

Magnetostrictive valves are useful primarily in cryogenic instrumentation. They are especially useful for controlling flows of liquid helium. Typically, a magnetostrictive valve is required to operate in a normally closed (energize-for-flow) mode. The magnetic fields needed for actuation of magnetostrictive valves like those reported previously can be generated by either normally conductive or superconductive solenoidal coils. It is necessary to supply current continuously to the solenoids to maintain the magnetic fields needed to keep the valves open.

SFTs for magnetostrictive valves could be made of bismuth strontium calcium copper oxide (BSCCO), as described in more detail in the preceding article. As in the case of a magnetostrictive heat switch, the main advantage of using an SFT (instead of a solenoid) to actuate a magnetostrictive valve is that the valve would remain in either the "open" or "closed" state until toggled into the opposite state by applying a pulsed current to a coil around the SFT to change the magnetic flux and thereby change the degree of magnetostriction. It may even be possible to select flux levels corresponding to states intermediate between "open" and "closed" to regulate flow; in that case, the valve would remain in the selected flow state, without power applied, until actuated into the next state.

The advantages of magnetostrictive valves actuated by either superconducting solenoids or SFTs are almost identical to those of similarly actuated magnetostrictive heat switches; low heat leakage, little or no thermal hysteresis, and functionality at the temperatures of the flows to be controlled. Valves actuated hydraulically with helium as the hydraulic fluid offer flow control with minimal thermal perturbation of cryogenic environments, but operate with response times about 100 times those of magnetostrictive valves.

This work was done by Robert Chave of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-20503

Liquid Shell Insulation

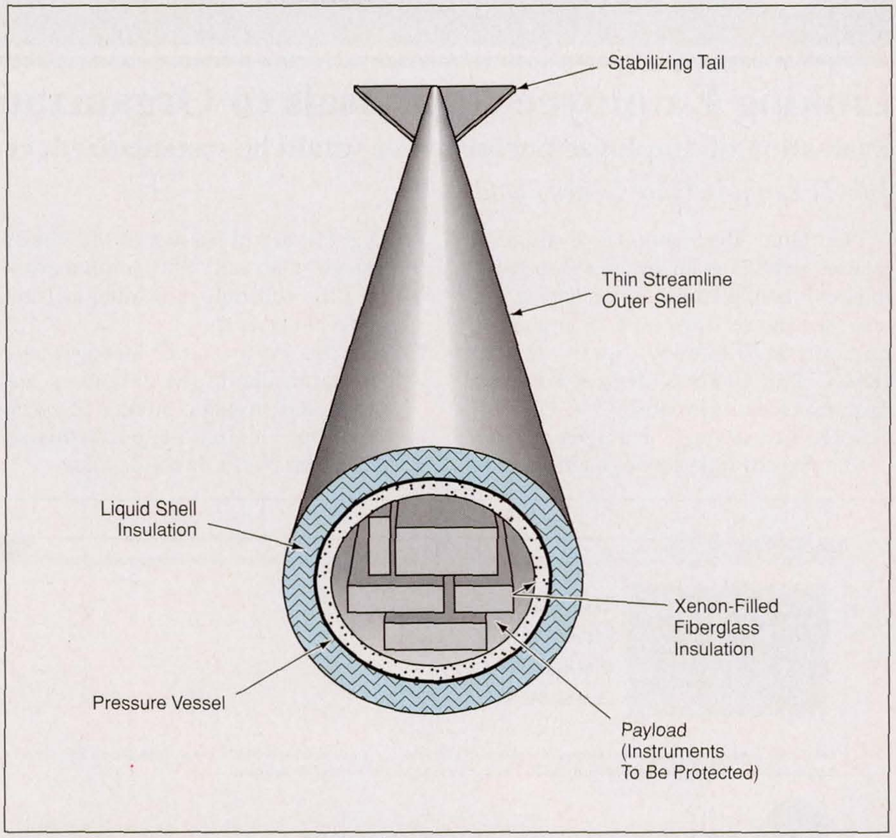
At high temperatures and pressures, probes would last just long enough to take readings.

NASA's Jet Propulsion Laboratory, Pasadena, California

A new concept called "liquid shell insulation" has been proposed as a means of temporary thermal protection for scientific instrument probes that are required to operate for short times in hot, high-pressure environments. Liquid shell insulation was conceived to protect probes that would be dropped from spacecraft to great depths in the atmospheres of the outer planets. For example, at a depth of 1,000 km on Jupiter, a probe would have to withstand a pressure of about 4,000 Earth atmospheres (≈0.4 GPa) and a temperature of about 1,800 K. On Earth, liquid shell insulation might be useful for protecting probes that would be inserted in undersea volcanic vents or deep oil wells.

The liquid shell insulation would be placed outside the pressure-bearing outer wall of a instrument probe; this would be done so that, in addition to the delicate instrumentation within, the outer wall would also be thermally protected. Thermal protection of the outer wall would be necessary to prevent the crippling loss of mechanical strength that would occur if the wall were allowed to be heated to 1,000 K or more.

As its name suggests, liquid shell insulation would be a shell-like structure, with a liquid-filled porous insulation material surrounding the pressure-bearing outer wall (see figure). The basic function of the liquid shell insulation would be to provide a sufficiently long characteristic thermal time so that the protected instruments would not exceed the maximum allowable temperature after the required collection and transmission of data has occurred. In addition to the liquid shell, the probe would be equipped with a streamlined external shell for low drag, so that it could descend to the required depth in a minimum time. The inner surface of the pressure vessel would be lined with a secondary insulating layer consisting of fiberglass with xenon gas filling the interstices; this layer would keep the instruments much cooler than the pressure vessel, which, in turn, would be much cooler than the environment.



A **Scientific Instrument Probe** would include instruments inside a pressure vessel that would be covered by liquid shell insulation that would, in turn, be covered by a streamlined outer shell. The liquid shell insulation would provide temporary protection against high ambient temperature.

The design of the liquid shell must combine the following features in order to function properly in a high-pressure, high-temperature environment:

- Low thermal conductivity to limit heating of the pressure vessel,
- High heat capacity to absorb most of the heat conducted in from the environment,
- Equalization of the pressure in the liquid with the ambient pressure to prevent loading of the thin streamlined outer shell;
- Means to prevent hot ambient gases from entering into the shell and compromising its insulating ability.

According to the current design concept, the liquid shell would be made of a porous solid filled with a liquid. To minimize the transfer of heat through the shell, the design and construction of the porous solid component must minimize spurious convective motion of the fluid and attenuate the radiative transfer of heat energy, while allowing some convective motion because of expansion and venting of the liquid as described below.

Both ammonia and water have been considered for use as the liquid. Both of these fluids have very high specific heat capacities and moderate thermal conductivities. Equally important, in the original planetary-exploration scenario, either of these fluids would slowly expand during atmospheric descent because the expansion due to heating would more than offset the shrinkage due to pressurization. Therefore, the shell would have to be open to the atmosphere through a check valve in order to equalize the pressure across the thin streamlined outer shell. The check valve would not only prevent ambient gas from entering the shell, but would also allow the expanding heated liquid to leave the shell, carrying heat with it. Although the liquid ammonia or water would expand during the atmospheric descent, it would not undergo phase change because the ambient pressure would greatly exceed the critical pressure of either fluid [113 atm (11.4 MPa) for ammonia, 220 atm (22.3 MPa) for water].

If ammonia were used, some of it would dissociate into nitrogen and hydrogen at high temperature. The endothermic dissociation reaction would absorb heat, thereby improving the overall insulating performance of the liquid shell.

This work was done by Jeffery L. Hall of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

NPO-20648

Linking Employee Appraisals to Organizational Goals

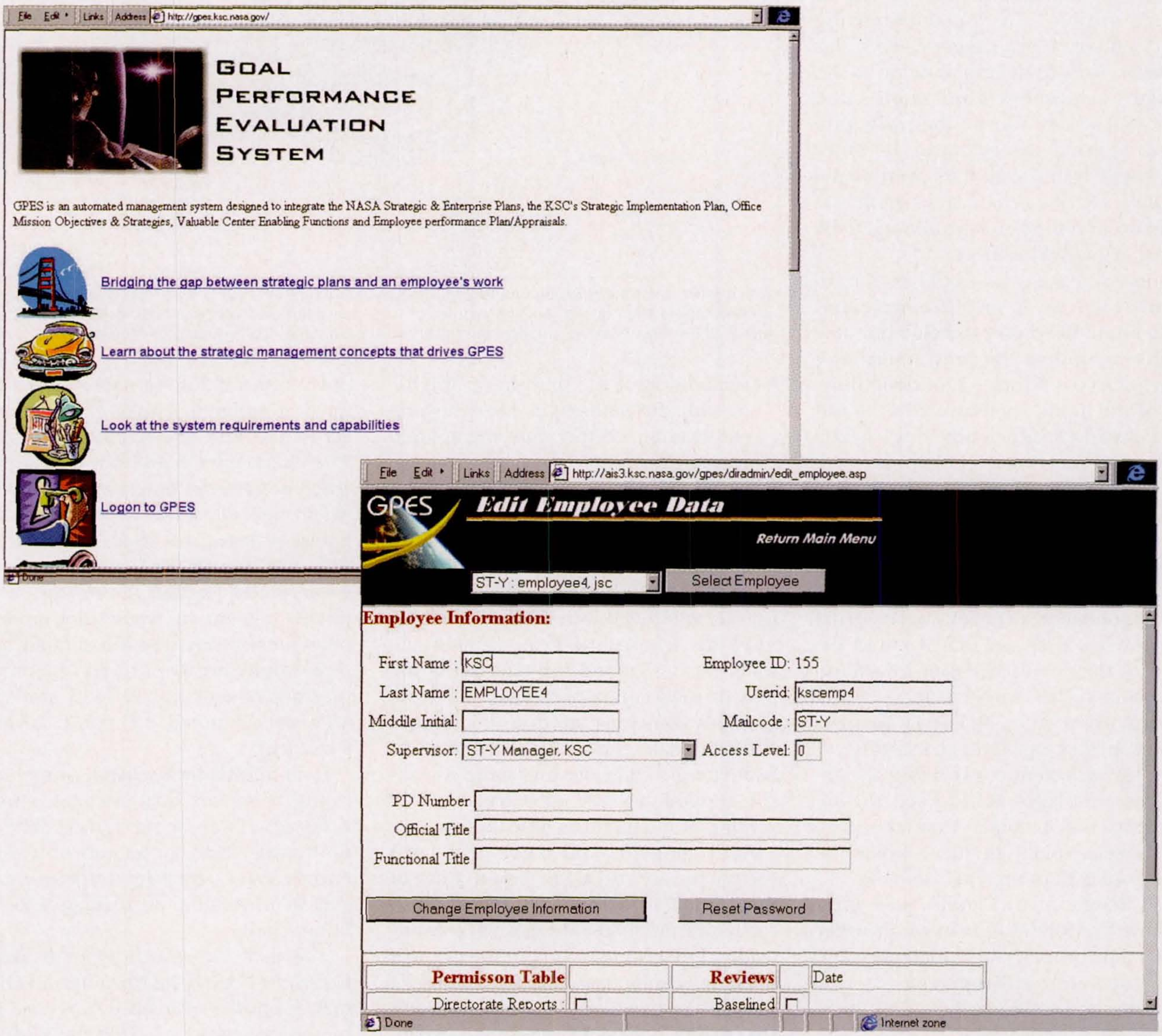
Evaluation of employee performance would be systematized, centralized, and automated.

John F. Kennedy Space Center, Florida

The Goal Performance Evaluation System (GPES) is an Internet-based automated management information system (see figure) now undergoing development at Kennedy Space Center (KSC). The GPES is designed to perform two major functions:

1. Serve as a strategic management tool that directly links through automation the goals and objectives of the NASA Strategic Plan and KSC Implementation Plan through individual performance plans; and
2. Serve as a Performance Management tool that facilitates the definition, appraisal, and strategic linking of every civil service employee performance plan to the NASA Strategic Plan.

According to NASA's Strategic Management Handbook, the final linkage between each employee's performance and high-level organizational goals is made via the employee's performance plan and appraisal, but heretofore, linkage processes had not been defined by NASA or by KSC. The GPES would define the linkage processes and



The **GPES Home Page** and a standard form for editing employee data are two examples of interactive displays provided by the GPES via the Internet, for use by employees and managers.

would serve as a central, systematic, automated means to implement the processes. The GPES consists of two parts: (1) the Integrated Business System Model (IBSM) and (2) a data-base application program.

The IBSM defines the documents and processes for relating NASA and KSC goals to the employee. The IBSM is an updated means of administering three management systems that have been in use at KSC: ISO-9000, Strategic Planning, and the Employee Performance Communication System (EPCS). The IBSM was developed to reduce the work of maintaining these systems and to improve understanding of interrelationships among them.

The data-base application program makes it possible to maintain all 1,700 employees' performance plans in one central data base. Some features of the program are the following:

- A manager adds items to an employee's performance plan by selecting them from a pull-down list of objectives and strategies.
- An employee can provide information on major accomplishments relevant to items in his or her performance plan. Additionally, the system facilitates the assimilation of employee/manager achievement data into office, directorate, and Center-wide reports.
- A manager can review information provided by an employee and add performance-assessment comments.
- The employee's performance plan can be printed on the KSC standard EPCS form.
- The program generates several reports, including one that shows a distribution of the number of employees contributing to each strategy.
- Performance plans for the entire Center can be changed simultaneously to reflect redirection in Agency/KSC Strategic Plans, or rephrasing of current objectives and strategies. Heretofore, each employee's performance plan was stated in a separate document, maintained by use of word processing software, that a manager or secretary had to update individually.

At the time of reporting the information for this article, the Internet application program has successfully completed its first performance development cycle both at KSC and at the Johnson Space Center. Based on the organizational and management benefits, Stennis Space Center is currently deploying the Internet application for the 1999 – 2000 year performance cycle. In addition, the Marshall Space Flight Center and the Langley Research Center are both evaluating the application as a pilot program.

Anticipated organizational benefits from the GPES, in addition to those mentioned above, include the following:

- Closer alignment between resources and high-level organizational goals;
- Increase in efficiency through automation and standardization of performance planning;
- Encouragement of cross-functional job assignments for employees through the on-line performance definition and assessment from multiple supervisors;
- Increase in communication;
- More feedback for better monitoring of how well the organization and its subdivisions are performing; and
- Facilitation of changes in organizational roles.

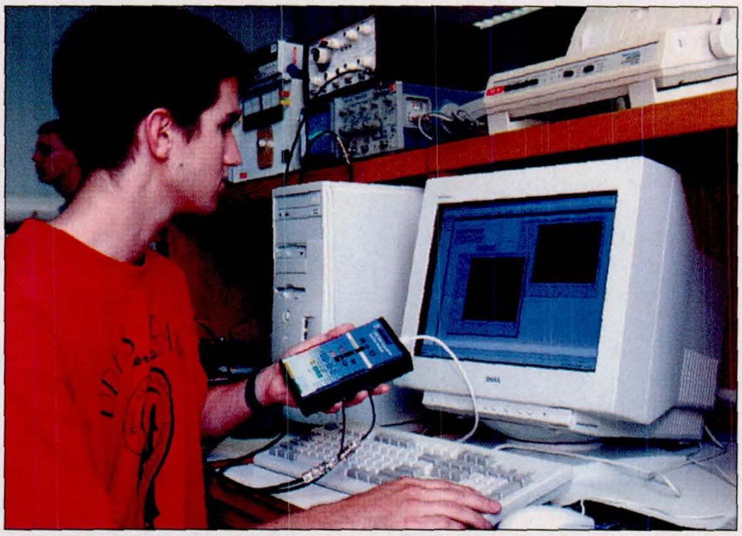
This work was done by Christopher J. Carlson, Jennifer C. Kunz, and Lesa B. Roe of **Kennedy Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (407) 867-6373. Refer to KSC-12036.

Choosing and Using USB Data Acquisition Peripherals

The Universal Serial Bus (USB), built into thousands of PCs and laptops, has undergone a major upgrade. Here's what you need to know about USB data acquisition, and other computer peripherals, controllers, and software.

USB 2.0 is poised to replace USB 1.1, offering 480 Mbs/s (megabits per second) data transfers (40 times the speed) and opening up new applications. The USB was created by a consortium of manufacturers — including Intel, Microsoft, and Compaq — to simplify the connection of external peripherals to personal computers. Unlike the ISA and PCI buses that require a user to open the computer to install a peripheral, all USB connections are on the outside of the box. A single, low-cost cable, which typically is supplied with the peripheral, carries power and signal connections, though some power-hungry devices may require external supplies.



A USB data acquisition function module device interfaces with Hewlett-Packard's Virtual Engineering Environment (VEE) software in Windows 2000.

USB devices are true plug-and-play. There is no setting of address lines, interrupts, or configuration jumpers. The host PC automatically identifies a peripheral when it is plugged in and searches for the software necessary to operate it. The first time a device is used, the user is prompted to install the drivers and application, a process that takes just a few minutes.

Expandability is another USB strong point. Up to 127 devices can connect to a single USB-equipped computer simultaneously, using expansion hubs and cable assemblies that are sold everywhere from computer shops to OfficeMax® and Wal-Mart®.

A Truly Universal Bus

With both Intel and Microsoft promoting it, acceptance of the USB has been enormous since its introduction about five years ago. Today, virtually all IBM- and Macintosh-compatible desktop PCs on the market provide two USB ports, and most laptops provide one. USB ports for older machines can be added using a PCI bus system controller board, which is available for less than $100.

Equally important, these USB ports have full software support under the most popular personal computer operating systems, including Microsoft Windows 98, Windows 2000, Mac OS 8.5 and 8.6, and the latest distributions of Linux. Support for individual peripherals is nearly universal under Windows and MacOS, but limited under Linux to popular devices such as mice, keyboards, printers, modems, and Zip drives.

Of greater interest to PC users, though, are the hundreds of USB peripherals currently available, including high-performance data acquisition modules. USB has supplanted serial, parallel, and even SCSI as the connection bus of choice for scanners, printers, modems, palm tops, digital cameras, and backup devices.

Mainstream data acquisition manufacturers like National Instruments, IOtech, and Data Translation offer USB alternatives to PCI and ISA plug-in boards. Typically, these USB data acquisition modules have performance, features, and software support comparable to conventional models. But they offer a significant advantage — portability. For perhaps the first time, users can move a data acquisition system between portable or desktop computers as easily as a Zip drive.

Data Transfer Speed

Despite its widespread acceptance, the main limitation of the USB has been technical. USB 1.1's 12 Mb/s data throughput is fine for moderate-speed applications, including most data acquisition uses, but not fast enough to support high-resolution printers and scanners, imaging, and highest-speed, megahertz-plus data acquisition applications. For example, 12 Mb/s translates to 1.5 MB/s (megabytes per second). But this is a theoretical number. In the real world, where bus overhead, system latencies, and other devices sharing the bus all slow things down, sustained 12- or 16-bit transfers of data acquisition samples are substantially slower, on the order of 300 to 400 kS/s (kilosamples per second).

This technical limitation has now been addressed. In April 2000, the USB 2.0 Promoter Group released the final 2.0 specification. USB 2.0 exceeds the previous version's speed barrier with 40 times the bandwidth: 480 Mb/s. Advances such as larger packet size and new transfer modes make high-speed transfers more efficient. As higher-performance USB peripherals become more widespread, 2.0's additional bandwidth will make it feasible to connect more USB peripherals, supporting multitasking software operations without slow-downs.

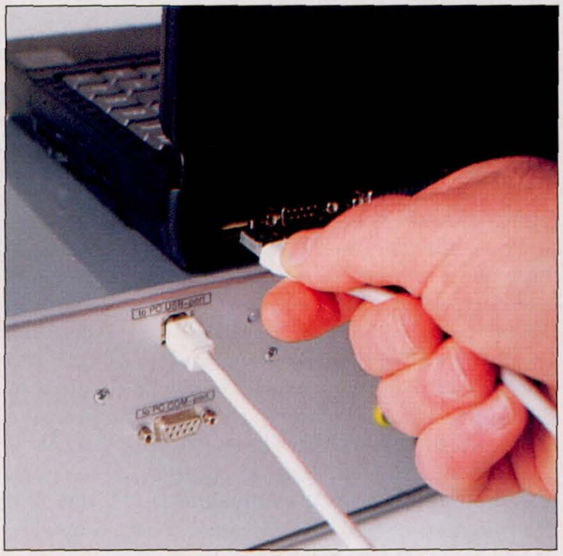
Since April, a mad dash has begun among hardware and software developers to create 2.0-compliant system controllers, hubs, and peripherals, and to ensure full support under Windows and MacOS. Dozens of peripherals are slated for release late this year, with more widespread availability in 2001. Data Translation is actively developing 2.0-compliant hardware, and it's safe to say that most data acquisition developers are planning to have 2.0 hardware when 2.0-ready computers start shipping.

As of August, however, the single event necessary to ensure 2.0's wide acceptance has not occurred — its inclusion in chipsets built into latest-model PCs from Dell, Compaq, Gateway, and Hewlett-Packard. It's expected that 2.0 eventually will replace 1.1 in PCs, but the changeover date is not clear — perhaps in 2001. For developers and other early adopters who can't wait, USB 2.0 can be had today: 2.0 is supported under the latest versions of Windows 2000; plug-in 2.0 system controller boards are available; and 2.0-compliant peripherals are starting to appear.

USB Data Acquisition Products

The convenience of USB and its high performance make it a natural environment for data acquisition. However, the requirements for a USB-based data acquisition system are a little different from those for more conventional ISA- and PCI-based systems. Here are a few things to check:

- **Self-Powered.** USB modules lose much of their convenience and portability if they require external power. This can be a problem, since USB modules are specified for far less power than PCI devices, but typically perform the same functions. With the speed limitations imposed by USB 1.1, this hasn't been a problem. But USB 2.0 will support the highest performance data acquisition devices, which also tend to be the most power-hungry. Look for single-function USB 2.0 modules.
- **Data FIFO.** Unlike PCI and ISA boards, USB modules do not use system interrupts. While this is a major installation convenience, it does mean that the device can wait a relatively long time before data transfers begin. Onboard FIFO buffers cache the data until the bus becomes available; 512 samples is a reasonable size for USB 1.x peripherals. Higher speed 2.0 devices are likely to need more.
- **Software Compatibility and Support.** Obviously, any data acquisition product should have full software support. This ranges from device drivers, SDKs (Software Development Kits), and ActiveX controls, to complete visual programming environments like HP VEE and LabVIEW. But if the USB module is not your first data acquisition device, choose a USB brand-mate that lets existing programs run with little or no modification. Look for products that use a consistent set of low-level driver calls to enforce device-to-device software compatibility.
- **Convenient and Flexible Connection Schemes.** Would you rather connect input and output devices directly to the USB module? Or is it more convenient to use a separate terminal panel and be able to disconnect everything at once? Make sure the data acquisition module you choose gives you the option you prefer. And, if you will be measuring thermocouples or RTDs, or require voltage isolation, make sure a well-integrated signal-conditioning option is available.



Users easily can move a data acquisition system between portable or desktop computers with plug-and-play USB devices.

While the bleeding edge of USB 2.0 systems and peripherals is already here, mass-market products have yet to arrive. With countless companies working on 2.0 products, it is just a matter of time before computer manufacturers announce that USB 2.0 is here. High-performance peripherals — devices like high-speed data acquisition modules that can't exist on 1.1 — are likely to lead the way. In the meantime, the evolution to 2.0 systems will not make previous products obsolete. And consider the advantages portable, expandable USB products offer over plug-in PCI alternatives.

For more information, contact the author of this article, Tim Ludy, product marketing manager for data acquisition, at Data Translation, Marlboro, MA; Tel: 508-481-3700; www.datatranslation.com.

Overview of Peripherals Buses

	PCI Bus	USB 1.1	USB 2.0	IEEE 1394
Speed	>/= 1 Gbits/s	12 Mb/s	480 Mb/s	>/= 400 Mb/s
Installation	Internal	External	External	External
Uses IRQs?	Yes	No	No	No
Expansion	No	Yes	Yes	Yes
Principal Use	Graphics Cards, Sound Cards, Disk Controllers	Peripherals	Peripherals	Digital Video
Max. Data Acq. Speed Supported	>1 Msamples/s	400 kS/s	>1 Msamples/s	NA*

*Not applicable because of the extremely limited availability of data acquisition peripherals.

Figure 1.

Special Coverage: Data Acquisition

Program Summarizes Operational Data From a Complex System

NASA's Jet Propulsion Laboratory, Pasadena, California

Engineering Data Summarization Flight Software is a computer program designed for use aboard a spacecraft to implement a concept, called "beacon monitoring," that has been discussed in several prior *NASA Tech Briefs* articles. The program generates summaries of operational data (e.g., sensor readings) that represent the state of the spacecraft, and thereby reduces both (1) the quantity of information that must be telemetered to a ground station and (2) the time and cost of analyzing the data to diagnose the spacecraft. The program can also be used to reduce the cost of diagnosing a complex terrestrial system. The program generates event-driven summaries of events since the last contact. For each event, the program identifies the sensor and its readout data that triggered increased monitoring, and gathers data from that sensor and causally related sensors at a high sampling rate around the time of the event. The data from all such events are assigned priorities and stored for downlink at the next telemetry pass. Gaps in the data between events are filled by "snapshots" of all sensor channels sampled at a lower rate. Triggering for each event can be effected by use of either static alarm thresholds or adaptive thresholds established by artificial-intelligence subprograms.

This program was written by E. Jay Wyatt, Dennis Decoste, Alan Schlutsmeyer, Robert Sherwood, and John Szijjarto of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www. nasatech.com*** *under the Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20822.

Neural-Network Approach to Analysis of Sensor Data

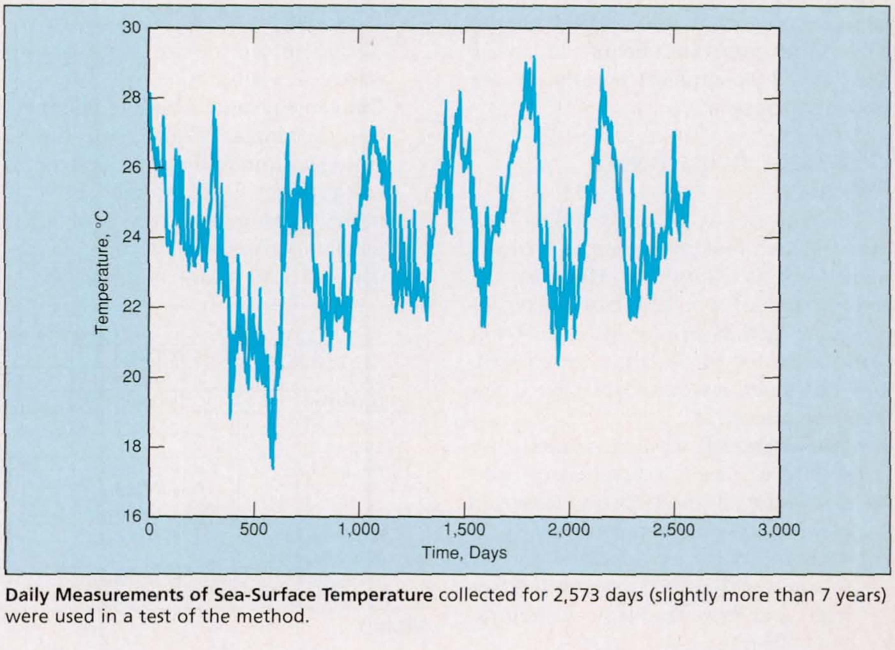
Anomalies in dynamic systems are detected by processing seemingly random time series.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of processing of time-series data from sensors that monitor a dynamic physical system has been devised to enable detection of anomalies in the dynamics. The method involves computing what are initially supposed to be dynamical invariants that represent the structural and operational parameters of the system; the invariants are specified in such a way that anomalies or abnormalities in the system manifest themselves as changes in the supposed invariants. The method could be applied, for example, to telemetric data from a spacecraft or to such time-series scientific data as sea-surface temperatures measured at daily or other regular intervals.

Abnormal behavior of the system can be detected by (1) predicting the future time series from current and previous time-series values, then (2) recording the actual time series going forward from the instant of prediction, then (3) suitably analyzing the differences between the predicted and recorded values. For the purpose of the present method, it is assumed that the invariants of the system can be represented by the coefficients of a differential or time-delay equation that represents the dynamics of the system.

An important element of the mathematical basis of the method is the concept that there are two types of abnormal behavior of a dynamic system: structural and operational. Structural abnormalities are caused by changes in the underlying dynamics and thus manifest themselves mathematically as changes in the supposed invariants. Operational abnormalities can be caused by unexpected changes in initial conditions or in external forces, but the dynamical model of the system remains the same. Mathematically, operational abnormalities are described by changes in nonstationary components of the time series. Structural and operational abnormalities can occur independently of each other.



Daily Measurements of Sea-Surface Temperature collected for 2,573 days (slightly more than 7 years) were used in a test of the method.

The major problems addressed by the method are how to build a dynamical model that simulates a given time series and how to develop the dynamical invariants, changes of which indicate structural abnormalities. Because the solutions of these problems are so multifaceted and complex that a description of them would greatly exceed the space available for this article, it must suffice to summarize them as follows: The solutions are based on progress in three independent fields — nonlinear dynamics, theory of stochastic processes, and artificial neural networks. One especially notable aspect of the method is that the dynamical model of a system is fitted to the previous and present time-series data by use of a feedfoward neural network that contains only one hidden layer. This technique of fitting is justified by a rigorous proof that any continuous function can be approximated by such a neural network.

The method has been tested by applying it to daily readings of sea-surface temperature collected by an instrumented buoy from May 1987 through May 1994 (see figure). The purpose of the test was to demonstrate that anomalies in the temperature dynamics could be found by use of the present method. Using knowledge of when El Niño and La Niña occurred, an attempt was made to show that the anomalies found by the present method correspond to these phenomena in some manner. An attempt was also made to formulate a way of using the method to predict El Niño and La Niña. At the time of reporting the information for this article, no conclusions concerning the efficacy of the method had been drawn, and there appeared to be a need for more experiments.

This work was done by Sandeep Gulati and Michail Zak of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Technology Reporting Office
JPL
Mail Stop 249-103
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240

Refer to NPO-20834, volume and number of this NASA Tech Briefs *issue, and the page number.*

Software for Acquiring Data on Dynamics of Magnetic Bearings

John H. Glenn Research Center, Cleveland, Ohio

A computer program controls the automated acquisition, display, and reduction of data on the dynamics of magnetic bearings. The data gathered by use of this program are expected to enable the verification and enhancement of mathematical models of magnetic-bearing dynamics, thereby contributing to the development of improved magnetic bearings for advanced gas turbine engines and other rotary machines.

With respect to a given magnetic bearing that is part of a rotary machine, the program acquires raw data on rotor position versus time during operation of the machine under known conditions of speed of rotation, temperature, electric currents applied to the electromagnet coils in the bearing, and shaking. The program processes the raw data to characterize the bearing with respect to dynamic position stiffness, current stiffness, and damping coefficients versus speed of rotation, eccentricity, bias current, temperature, and frequency of shaking. The program can also account for friction, stiffnesses of structural supports, inertia, and uncertainties.

The program was developed by use of the LabVIEW software system and the corresponding NI-DAQ programming language. The program provides the user with four major options called "16 Time," "16 Frequency," "Stiffness," and "Alignment." The first two options enable the monitoring of 16 analog input channels to obtain time- and frequency-domain responses. These options also enable the generation of four orbit displays and provide for the recording, in a text file, of the magnitudes and phases of the components of motion at the shaking frequency. The Stiffness option provides for the measurement and recording of the position and the current stiffness of the magnetic bearing, using data from 14 input channels. The stiffness option also includes a provision for calculating uncertainties. The Alignment option generates a graphical display of stator alignment with a bar chart of eight dynamic load cells.

This program was written by Gerald Montague and Al Kascak of the U.S. Army Research Laboratory and Alan Palazzolo of Texas A & M University for **Glenn Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17057.

Fluorometer for Analysis of Photosynthesis in Phytoplankton

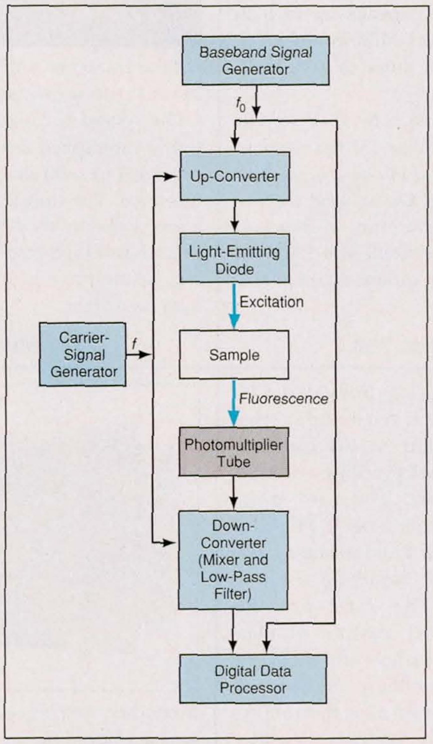
Measurements could be made *in situ* and *in vivo*.

Stennis Space Center, Mississippi

An instrument that measures the characteristic lifetime of fluorescence of chlorophyll has been invented for *in situ,* real-time oceanographic studies of photosynthesis in phytoplankton. The basic design and principle of operation lend themselves to development of the instrument as a relatively inexpensive, sensitive, compact, rugged, portable, low-power-consumption, hand-held, shipboard unit. Similar units with designs adapted to agricultural applications (e.g., assessment of physiological statuses of crops) are also envisioned.

The need for this or a similar instrument arises because fluorescence lifetimes are robust measures of physical and chemical mechanisms that affect photosynthesis and of the photosynthetic productivity of phytoplankton. The fluorescence lifetimes of particular interest are those associated with fluorescent de-excitation in photosystem II. ("Photosystem II" denotes a series of photosynthetic reactions in which a pigment absorbs light at wavelengths up to 680 nm and absorbed light energy causes the splitting of water molecules, giving rise to oxygen and to a high-energy reductant.) These lifetimes range from about 2 ns down to as little as hundreds of picoseconds. Therefore, in order to exploit the full potential of fluorescence-lifetime measurements for detecting small changes in photosystem-II physiological status, this or any similar instrument would have to exhibit an error <50 ps and a resolution ≈10 ps.

The present instrument does not measure fluorescence lifetimes directly; instead, it is based on a principle of phase fluorometry, which can be implemented more easily. In phase fluorometry, a sample is excited with light modulated sinusoidally at an angular frequency ω. The resulting fluorescence emitted by the sample is modulated at the same frequency but, because of the finite lifetime of the excited state, is delayed in phase by an angle ϕ relative to the excitation. The phase angle ϕ is measured and used to calculate a phase lifetime (τ_p) according to $\tau_p = \tan \phi / \omega$. In order to be able to determine τ_p accurately by this method, one must choose a modulation frequency comparable to the rate of decay of the fluorescence.



This **Instrument Measures the Phase Difference** between sinusoidally modulated optical excitation and the resulting fluorescence. The fluorescence lifetime is then calculated from the phase difference and the modulation frequency.

In the instrument (see figure), a baseband signal of frequency f_0 (typically 600 Hz) is generated for use both as a sample signal and as a reference signal for the phase measurement. Using a single-sideband technique, the sample signal is up-converted by combining it with a carrier signal of frequency f (typically 70 MHz). The up-converted signal (at frequency $f_0 + f$) is used to modulate a light-emitting diode (typical wavelength 670 nm), the output of which is used to excite the sample.

The fluorescence emitted by the sample acquires a phase delay that corresponds to a frequency-dependent weighted average of the lifetimes of the fluorophores present in the sample. The fluorescence, which is modulated at frequency $f_0 + f$, is detected by a photomultiplier tube. The electrical output of the photomultiplier is down-converted to f_0 by mixing it with the carrier signal and low-pass filtering the product signal. The phase information acquired by the up-converted signal through interaction with the sample is preserved in the down-converted signal. The phase-shifted down-converted f_0 sample signal and the reference f_0 signal are captured by an analog-to-digital converter, and the output of the analog-to-digital converter is stored and processed to determine ϕ and τ_p.

This work was done by Salvador M. Fernandez, Ernest F. Guignon, Robert Kersten, and Ernest St. Louis of Ciencia, Inc., for **Stennis Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Ciencia, Inc.
111 Roberts Street
Suite K
East Hartford, CT 06108

Refer to SSC-00110, volume and number of this NASA Tech Briefs *issue, and the page number.*

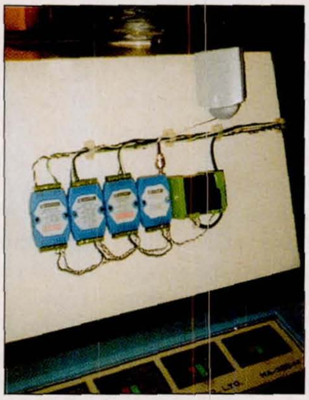
Program for Visualization and Exploration of Scientific Data

NASA's Jet Propulsion Laboratory, Pasadena, California

WebWinds is an interactive computer program that aids the visualization and exploration of scientific data. WebWinds is the successor to LinkWinds, which was reported in "LinkWinds — Flexible Software for Highly Interactive Visual Data Analysis" (NPO-19786), *NASA Tech Briefs,* Vol. 20, No. 12 (December 1996), page 46. WebWinds is a platform-independent, reusable code written in the Java computer language. WebWinds has been tested on Linux, Sun, SGI, and Win95 systems.

This program was written by Martin Orton, Lee Elson, Jeff Goldsmith, and William Weibel of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*

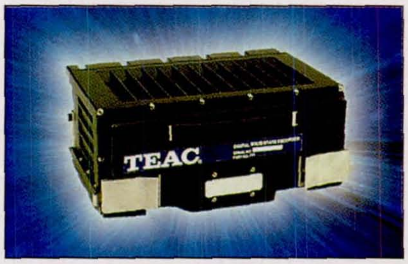
This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20685.



Quatech, Akron, OH, has introduced the QTM-8524 Direct Sequence Spread Spectrum (DSSS) RF modem modules for **wireless data acquisition** in industrial monitoring and control applications. The modem modules operate in the 2.4-GHz ISM band and can reach speeds up to 57.6 Kbps. They use GMSK modulation, making them suitable for high-noise environments.

The modules convert RF signals to serial RS-232 or 485 for communication with a PC or a serial network. They can be used to network PCs and PLCs, or used in conjunction with data acquisition and signal conditioning modules to create a modular data acquisition and control system. The standard package includes either an indoor/outdoor wall-mount swivel antenna or a ceiling-mount antenna.

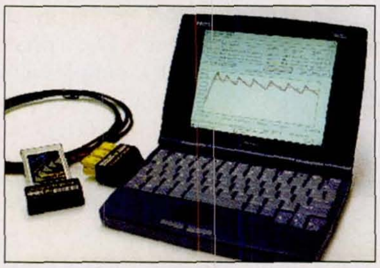
For More Information Circle No. 708



The SSMDR solid-state **data recorder** from TEAC America, Montebello, CA, weighs less than 9 pounds, measures 8.7 x 6.0 x 3.75", and consumes less than 50 watts. It is designed as a removable recorder/reproducer, and comes standard with the AMPEX DCRsi™ interface, which provides compatibility with existing data acquisition systems and ground data analysis systems.

The system is capable of simultaneous recording of data received over a high-speed input interface, while playing back data previously recorded in solid-state memory through a high-speed parallel output interface. The unit features an array of up to 32 PCMCIA cards, with a total capacity of 50 GB. The system can be mounted in a rack, integrated into high-resolution sensor packages for direct digital recording, or mounted in a Form Fit Function adapter to replace existing data recorders.

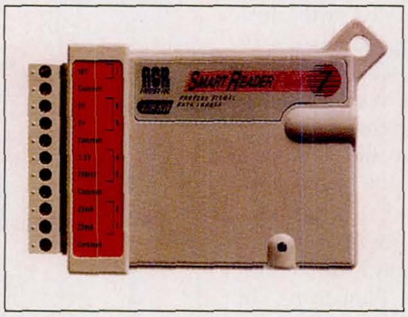
For More Information Circle No. 707



Nomadics, Stillwater, OK, has introduced the TCChart, a PC card for **thermal profiling and data analysis**. The card plugs into the Type II PC Card slot on Windows-based laptop or handheld computers. The card provides thermal analysis of electronic circuits, thermal controls, engine performance, and mechanical fatigue. It provides six-channel, real-time profiling and data collection of thermal processes measured with any of nine thermocouple types or IR sensors.

The card displays the rate of temperature change, and the time-stamping of maximum and minimum temperature for each channel. After completing the profile, users can perform additional on-screen analysis, including overlaying two profiles to compare data between different test runs. The system includes the PC Card, software, and six thermocouples.

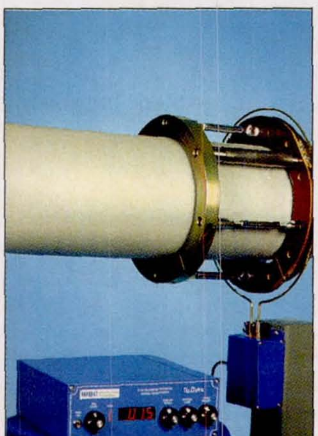
For More Information Circle No. 709



The SmartReader Plus® Model 7 pocket-sized **data logger** from ACR Systems, Surrey, BC, Canada, features one internal temperature channel and seven analog inputs. With a variety of transducers connected to it, the unit can measure and record variables such as relative humidity, pressure, current, voltage, flow, vibration, torque, and acceleration.

The logger can store 87,000 readings and comes with a 10-year battery. It can be placed at a remote site, and via modem, a user can change the settings or download data. The logger includes an alarm dial-out feature that enables it to dial from a remote site to notify the user of an alarm condition. Logged data can be retrieved to a PC and displayed graphically and statistically.

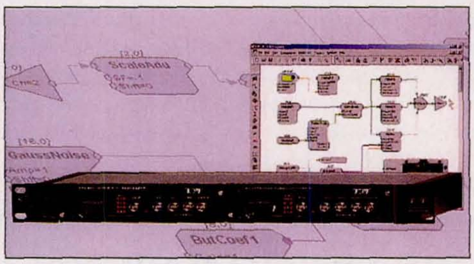
For More Information Circle No. 710



Wireless Data Corp., Columbus, OH, offers the Model 2100 **wireless sensor system** that collects up to 10 different channels of wireless data from sensors mounted on rotating shaft installations. There are no physical connections between the transmitter and receiver, and no modification is required of the rotating device.

The system delivers wide-bandwidth data from dc to 1000 Hz, and uses an 8-pole filter for data integrity. The system's transmitters are designed for shafts up to 42" in diameter, rotating at up to 12,000 RPM. It operates in temperatures up to 125°C. It features high sensitivity for low strain gage outputs, and comes with patented Calibrate Any Time (CAT) technology.

For More Information Circle No. 705



The RP2 Real-Time Processor from Tucker-Davis Technologies, Gainesville, FL, is a **data acquisition/processing** unit that combines a real-time digital signal processor (DSP) with stereo 24-bit DACs and ADCs, with a USB interface. The system supports more than 120 DSP functions, and features eight digital inputs and eight digital outputs.

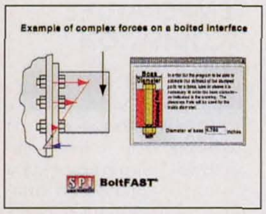
The processor's DSP algorithms can be used to filter signals or run a real-time signal detection algorithm. The unit comes with 16 MB of memory for storing signal data, which can be downloaded via the USB interface. Applications include experimental control, dynamic signal generation, real-time filtering, and signal averaging.

For More Information Circle No. 706

New on DISK

Virtual Reality Development

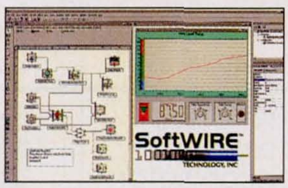
Engineering Animation, Ames, IA, has introduced WorldToolKit Release 9 for Linux, a cross-platform software development system for creating real-time, 3D, interactive and virtual reality applications. The new version includes a C/C++ programming interface. A function library includes tools for creating, editing, controlling, deploying, and commercializing 3D interactive and VR applications. It also supports network-based distributed simulations and interface devices such as head-mounted displays, trackers, and navigation controllers. **Circle No. 720**



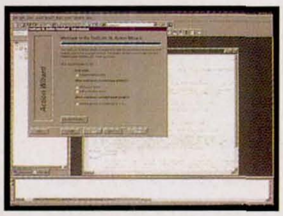
Joint Fatigue and Analysis

BoltFAST® bolted joint analysis software from Sensor Products, East Hanover, NJ, is a Windows-based program that enables engineers to determine the fatigue endurance limit of a thread, the amount of embedding anticipated in the joint, and the optimal tightening torque for given friction conditions. Users can evaluate "what if" scenarios via three main components: a Joint Analysis program; a Thread Analysis program; and a Torque Analysis program. **Circle No. 721**

Graphical Programming



ComputerBoards, Middleboro, MA, has released SoftWIRE™ 2.0, a graphical programming add-in for Visual Basic 6.0. It allows non-programmers to use Visual Basic to create programs. The new version features an advanced database, and TCP/IP, arithmetic, and analysis functions. New Excel functions provide options to create charts and spreadsheets. Three new database options allow users to run a query builder, create a database grid, and read and write from an Access, Oracle, or SQL database. **Circle No. 722**



Test System Control

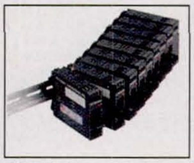
TestExec SL 4.1 from Agilent Technologies, Palo Alto, CA, is a standalone program for controlling test system operation and automating test engineering tasks. Features include test sequencing, limit checking, data logging and export, and operator interfaces. Users can view test data over the Internet using TestExec SL's XML data export capability. The software operates on Windows NT/2000, and supports a variety of programming languages. **Circle No. 723**

Technical Research and Analysis

Invention Machine Corp., Boston, MA, offers Knowledgist™ 2.0 for technical research and analysis. Using a semantic technology engine, the software processes large volumes of information and analyzes the interaction between words and the meaning of word combinations. Based on complex algorithms, the engine divides the content into sentences, analyzes the sentences, and creates a structured knowledge index based on the meaning of the word combinations. The new version offers the capability to analyze Web-based sources, in addition to local information sources. It includes search access to over 700 Web sites grouped by industry. **Circle No. 724**

DESIGN ENGINEERING PRODUCT SHOWCASE

New Products and Services for* NASA Tech Briefs *readers. For more information, write in the corresponding number on the Free Information Request Card (following page 24).

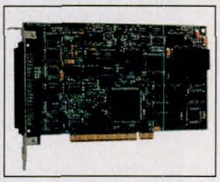


PROGRAMMABLE SIGNAL CONDITIONERS

The DRN/DRX Series programmable signal conditioners/transmitters from OMEGA are available for thermocouple, RTD, process voltage, strain, frequency, pulse, AC voltage, and current. They are priced at $250, feature up to 1800 Vdc isolation, free ActiveX controls, and factory configuration at no charge. The DRN Series provides 0-10 Vdc, 4-20 mA, or 0-20 mA output; the DRX Series provides RS-485 output (OMEGA Serial Protocol and MODBUS Serial Protocol). OMEGA Engineering, One Omega Dr., Stamford, CT 06907; Tel: 1-888-TC-OMEGA; www.omega.com

OMEGA Engineering Inc.

For More Information Circle No. 600



MULTIFUNCTION BOARD FOR PCI-BUS

OMEGA's PCI-DAS1200 Series low-cost, high-speed, multifunction board for the PCI bus offers 8 differential/16 single-ended analog inputs, 12-bit A/D resolution, 330 KHz sample rate, and dual 12-bit analog outputs. Priced at $649, the board also features 1024 sample FIFO, 24 bits of digital I/O, and is fully plug-and-play. OMEGA Engineering, One Omega Dr., Stamford, CT 06907; Tel: 1-888-TC-OMEGA; www.omega.com

OMEGA Engineering Inc.

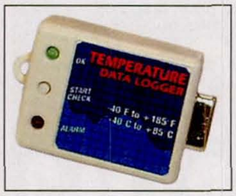
For More Information Circle No. 601

TEMPERATURE ACQUISITION MODULE

The OMEGA OM-MT20 temperature acquisition module measures, views, collects, and analyzes temperature data using your handheld computer. Stored data is easily transferred from the handheld computer to your PC. Connect up to two external thermocouples. The $389 module is lightweight, compact, durable, and battery-powered. OMEGA Engineering, One Omega Dr., Stamford, CT 06907; Tel: 1-888-TC-OMEGA; www.omega.com

OMEGA Engineering Inc.

For More Information Circle No. 602



PORTABLE DATALOGGER

OMEGA offers the OM-61 low-cost portable datalogger, part of the NOMAD® family. Featuring user-selectable stop on memory full or memory rollover for continuous recording, the datalogger is priced at $69. Other features are a real-time clock, temperature alarm with visual indication on demand, and PC or push-button recording control. OMEGA Engineering, One Omega Dr., Stamford, CT 06907; Tel: 1-888-TC-OMEGA; www.omega.com

OMEGA Engineering Inc.

For More Information Circle No. 603

PC-BASED DATA ACQUISITION

The DI-720/730 Series PC-based industrial data acquisition systems from OMEGA include standard printer port, optional USB or Ethernet interface, and 16-bit resolution in the DI-720 model. Prices start at $1,195 for the DI-720-P. The DI-720 also has 32 16-single-ended inputs; the DI-730 has 8 isolated inputs (10 mV to 800 volt range). OMEGA Engineering, One Omega Dr., Stamford, CT 06907; Tel: 1-888-TC-OMEGA; www.omega.com

OMEGA Engineering Inc.

For More Information Circle No. 604

PCMCIA TEMPERATURE MEASUREMENT CARDS

OMEGA's PC-TC6 and PC-TM3 PCMCIA cards for temperature measurement are compact in size and offer automatic cold junction compensation, miniature thermocouple inputs, and programmable ground referencing. They support all common T/C types, as well as a wide range of RTDs and thermistors. A 1/4" phone jack input also is included. The cards are priced at $695. OMEGA Engineering, One Omega Dr., Stamford, CT 06907; Tel: 1-888-TC-OMEGA; www.omega.com

OMEGA Engineering Inc.

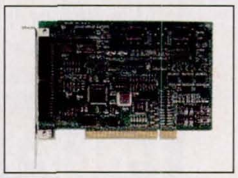
For More Information Circle No. 605

DIRECT SENSOR TO DATA ACQUISITION

OMEGA's instruNet Series direct sensor to data acquisition provides high-accuracy data acquisition for Windows 95/NT and Macintosh computers. It includes strip/chart software and drivers for C, Visual Basic, HP VEE, and TestPoint; optional LabVIEW drivers also are available. Other features include 16 single-ended/8 differential 14-bit analog inputs, 8 analog outputs, and 8 digital I/O. The controller card includes 10 counter/timer channels. The unit offers direct connect to RTD, thermocouple, voltage, thermistor, bridge, and strain gage sensors. Prices start at $890. OMEGA Engineering, One Omega Dr., Stamford, CT 06907; Tel: 1-888-TC-OMEGA; www.omega.com

OMEGA Engineering Inc.

For More Information Circle No. 606



PCI BUS BOARDS

PCI-5500 low-cost, high-speed, multifunction boards for the PCI bus from OMEGA are available with 12- or 16-bit analog inputs, sampling rates to 200 kHz, and offer 8 differential and 16 single-ended inputs. The boards start at $199 and feature multiple triggering modes, 16 digital I/O lines, and optional dual D/A voltage outputs. They are fully plug-and-play with no jumpers or switches, and are fully auto-calibrating. OMEGA Engineering, One Omega Dr., Stamford, CT 06907; Tel: 1-888-TC-OMEGA; www.omega.com

OMEGA Engineering Inc.

For More Information Circle No. 607

LOW-COST DATALOGGERS

Omega's OM-DL Series portable, low-cost dataloggers, part of the NOMAD® family, are for use with any PC or the OM-DP3 Data Plotter. The OM-DL connects to a PC parallel printer port and provides locking protection to prevent accidental shutoff. The OM-DP3 Data Plotter also can be used as a conventional chart recorder. The compact, lightweight, easy-to-use OM-DL is priced beginning at $80. OMEGA Engineering, One Omega Dr., Stamford, CT 06907; Tel: 1-888-TC-OMEGA; www.omega.com

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For More Information Circle No. 608

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New on the MARKET

Multi-Function Calibrator

Omega Engineering, Stamford, CT, offers the CA100 compact, multi-function calibrator for on-site use in process industries and equipment diagnostics. A single unit can be used to generate a DC voltage, DC current, resistance, temperature, and frequency. It provides a 24 Vdc power supply for calibrating transmitters, and for measuring DC voltage, DC current, and resistance. **Circle No. 700**

AC/DC Power Supply

The NW Series of modular AC/DC power converters from Martek Power Abbott, Los Angeles, CA, have an operating temperature range from -40°C to 100°C. The modules provide drop-in replacement for existing products when wide temperature performance is required. They are available in 25- and 50-Watt output versions with single and dual output channels. Standard features include remote sense and remote logic on/off, as well as protection for over-voltage, over-current, and over-temperature shutdown. The converters are suitable for RF, signal processing, and motor drive applications. **Circle No. 701**

Touchscreen Workstation

AutomationSolutions, Petaluma, CA, has introduced the AS-100 high-resolution workstation with touchscreen for harsh environments. The 14.1" TFT LCD display features a 6-slot passive backplane and a steel chassis. It also features a 4/12 sealed aluminum alloy front panel, and provides a NEMA-rated mount. It operates in temperatures from 0°C to 50°C, and comes with Windows 98 or NT 4.0. It features a single-board computer with a Pentium 233-MHz processor, a 6.4-GB hard drive, and 32 MB to 128 MB of RAM memory. Other features include a 250W power supply, CD-ROM, floppy drive, and optional resistive touchscreen. **Circle No. 703**

Optical Isolator

BEI Industrial Encoder Division, Goleta, CA, offers a DIN rail-mountable, optically isolated electronic module for use with incremental encoders. The optical isolator provides an electrical output to the receiving electronics. By providing an interface between the encoder and the receiving electronics, the unit can be used to eliminate ground loops, reduce signal degradation from long cable runs, or provide a means to distribute an encoder signal to multiple input devices. **Circle No. 704**

Custom EMI Filters

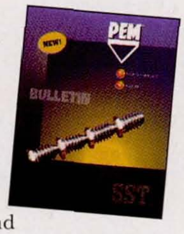
Electrocube, Monrovia, CA, has introduced custom EMI filters designed for applications in the military, industrial, aerospace, and electronics markets. The filters feature current-carrying capacities of 0.1 amp to 500 amps, voltage ratings of 1 VDC to 5,000 VDC, and frequencies to 1,000 Hz. Single and multi-circuit configurations include L, Pi, Pi with feed-through capacitors, and T circuits. Enclosures can be designed to conform to specific space and mounting constraints, and termination requirements. **Circle No. 702**

New LITERATURE

Industrial Instruments

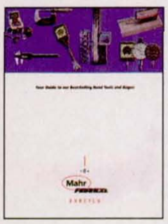
Cole-Parmer Instrument, Vernon Hills, IL, has released its 2001/2002 general catalog of industrial instruments and equipment. The 2,200-page catalog features equipment for biotechnology, electrochemistry, industrial, and safety applications. Products include calibration equipment, instrumentation, pipettes, screening devices, and semiconductor equipment. **Circle No. 725**

Screw Insertion System



Penn Engineering & Manufacturing Corp., Danboro, PA, has released a four-page brochure on the STICKSCREW® System for small-screw insertion. The self-contained system allows for easy attachment of metal or plastic components. The brochure profiles standard machine screw thread sizes, materials, lengths, and other specs. Tool options included in the brochure are Pistol Grip and In-Line StickShooter™ air tools. **Circle No. 730**

Hand Tools and Gages



A 20-page catalog of hand tools and gages is available from Mahr Federal, Providence, RI. Products include calipers, micrometers, test indicators, dial indicators, digital electronic indicators, height gages, and electronic gaging products. Also featured is the Pocket Surf® line of portable surface roughness gages. **Circle No. 726**

Microelectronic Packaging

Remtec, Norwood, MA, has released an eight-page brochure describing microelectronic packaging solutions, including the company's Plated Copper on Thick Film (PCTF)™ manufacturing process. The technology combines patterned copper-plated images with air-fireable thick films on ceramics for the manufacture of metalized substrates, chip carriers, and packages. **Circle No. 729**

Grippers and Automation Components

A CD-ROM and 64-page catalog of pneumatic and hydraulic grippers is available from Techno-Sommer Automatic, New Hyde Park, NY. The CD features more than 1,000 automation components, including grippers, swivel units, tool changers, linear and rotary actuators, vacuum technology, and shock absorbers. Free .DXF CAD file drawings of all other components are available on the CD-ROM. **Circle No. 727**

Ballscrew Assemblies

Ball Screws & Actuators, San Jose, CA, offers a 120-page catalog of plastic nut, leadscrew, and ballscrew assemblies for linear motion applications. It also features new products such as the XCM 1800 plastic nut. Other new products include anti-backlash nuts, and additional screw sizes in English and metric units. **Circle No. 728**

Editorial Index

Use the Web addresses listed below to obtain more information from the following companies featured editorially in this issue.

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FREE NEWSLETTER

This Month in

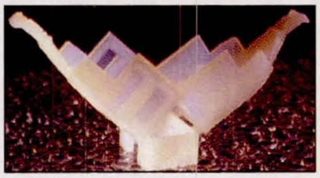
Rapid Product Development online

The web publication for *NASA Tech Briefs* readers

NASA Tech Briefs' *all-digital publication, Rapid Product Development Online (**www.rapidproducts.net**), helps engineers develop better products faster by providing immediate 24-hour access to the latest information on CAD, FEA, modeling, mold-making, reverse engineering, and rapid prototyping tools and techniques. This month's RPD Online includes:*

Advanced Resin Allows Production of Parts With "Living" Hinges

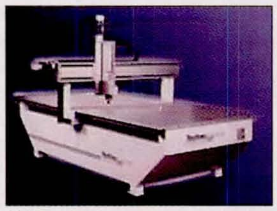
Tyco Electronics, a supplier of electrical connection devices under the AMP trade name, has been using stereolithography for more than a decade. However, an AMP connector design requirement specified the production of stereolithography parts containing living hinges. Living hinges are made completely out of plastic; instead of having a metal linkage at the point of actuation, a living hinge's plastic fibers bend to complete a given motion. After experimenting with DSM Somos 8100 resin, Tyco now can achieve stereolithography success.



www.rapidproducts.net/Nov00/hinges1100.html

Router Helps Prototype Maker Increase Sales

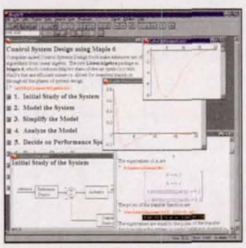
The improved accuracy of a computer numeric controlled (CNC) router from Techno-Isel has helped generate a 30% increase in sales at Modelmakers, Inc., a manufacturer of plastic prototypes. Previously, the prototypes were made by manually cutting parts out of plastic sheet stock and gluing them together. Using the router, designs are carved out of plastic blocks, which are used to produce silicone molds for urethane castings. The cast prototypes, generated from CAD data, are more accurate than the piece-together models, resulting in increased repeat business.



www.rapidproducts.net/Nov00/router1100.html

How to Use Numeric Components as Software Development Tools

Rapid product development hinges on the speedy and cost-efficient development of reliable software with built-in error handling mechanisms. Software vendors understand that the key to their profitability lies in licensing previously tested code. Extensively tested routines found in numeric and statistical libraries are a popular choice in that they preclude the need to "reinvent the wheel." The experiences of three companies — Datacolor, Waterloo Maple, and Intel — illustrate the advantages of using well-established numeric algorithms as software development tools.



www.rapidproducts.net/Nov00/software1100.html

New Product Highlights

Flexane® castable liquid urethane compounds from Devcon, Danvers, MA, cure to form flexible and rigid rubber parts for a variety of OEM applications. The room-temperature-curing, nonshrinking urethanes do not change shape while curing, and can be used to make precision molds that reproduce fine details. They also provide an easy way to pour and mold cast rubber replacement parts that have been discontinued.

www.rapidproducts.net/Nov00/products1100.html

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Eastman Kodak Company is changing the way decisions are made — providing information from imagery to people, on demand.

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RSI will operate as a wholly owned subsidiary, retaining its unique brand and market-leading position. Together, Kodak and RSI will offer many exciting new products, services, and exceptional customer service. With RSI as a member of the Kodak family, we have further secured our position as the leading provider of all your information needs. To RSI employees, we extend a heartfelt "welcome aboard."

For More Information Circle No. 532